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THE RELATION OF CLIMATE AND BODY SIZE IN U. S. MALES

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INTRODUCTION

The recent interest in the application of ecological rules to man has produced impressive evidence of association between elements of body size and temperature (Schreider, '50; Roberts, '53). The basic precepts of Bergmann's rule and its application have been fully covered by M. T. Newman ('53) and need only to be summarized here. In brief, Bergmann's rule states that subspecies' body size increases in colder climates and decreases in warmer climates. This is related by Schreider to the physical principle that the ratio of heat generating mass (body weight) to heat eliminating mechanism (body surface area) varies from high ratios in colder climates to lower ratios in warmer temperatures.

Despite the completeness of the works cited above in establishing the association between body size and climate, there are several limitations to the published data which allow a further exploration along somewhat different lines without risk of unnecessary duplication of effort or belaboring the general hypothesis. Specifically, M. T. Newman's work on New World aborigines suffered from an unfortunate lack of data on body weight and no detailed examination of temperature; Schreider's series was small in number of groups and lacked temperature data; and Roberts' worldwide analysis included groups of obviously different nutritional and occupational backgrounds. The correspondences which they demonstrated were far from ideal and the addition of material on another population might clarify some of the previous work.

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The samples published by Schreider and Roberts are preponderantly drawn from what are termed ‘‘primitive’’ peoples. Roberts has included a regional analysis of Britain and utilized Finnish material, but neither of these areas are characterized by marked differences in mean annual temperature. Although it is fairer to say that both of them utilized wide-spread groups to obtain maximal climatic difference, it seems to be a current impression that it is principally the ‘‘primitive’’ who is influenced by his environment. Newman speaks of the ‘‘strongly shielding effect of high culture,’’ although this concept is offered as rebuttal to those who deny or minimize the occurrence of adaptive alterations in recent man. This latter hypothesis can be tested by examination of a ‘‘civilized’’ population whose habitat includes a range of environmental conditions. The United States provides such a population, and it is a rare American who has not remarked frequently on either the hot summers or cold winters, or both, which complicate and impinge on his daily activities.

The examination of the applicability of a youthful, white, United States male population to Bergmann’s rule presents both advantages and disadvantages when compared to the material cited above. Before starting the detailed analyses of this series of approximately 15,000 American males, we wish to acknowledge our debt to the authors already cited and present this as a corollary to their work.

DESCRIPTION OF THE POPULATION SERIES

The series used here consists of 15,216 native-born, white males. The body measurements were obtained upon their induction into the United States Army. The series is actually a composite of three separate investigations: 8,421 in 1946; 5,104 in 1949; and 1,691 in 1953. Since this is a series of those accepted for military service, a few of the possible sources of bias can be mentioned immediately. One, it is a series of healthy young men, although the influence of this fact on the physical dimensions used here is unknown. Two, it has been subjected to a screening at the lower limit of 60 inches and 105 pounds by Army induction standards. Individuals below these limits occur occasionally, evidently through incomplete screening or errors in measurement. Three, it is a very homogeneous sample in regard to age. It may be too young a series for best analyses because some small increment in both stature and weight can be anticipated before adult growth is complete. Since the subdivisions of the sample are practically identical in average age (see appendix A), any intra-series comparison does not suffer from this source of error. Four, it must be noted that although this is a military series, these men are inductees measured before training and not yet subjected to the influence of a military environment.

The geographic provenience of these men was determined by their state of birth. This introduces a source of error into the data since it is obvious that not all men remain in their natal state until induction into the Army. Although it was not possible to ascertain the proportion of migration within the United States in this series, a rough comparison between the area of birth and place of induction indicated that only a small percentage of the men showed gross discrepancies between these areas, for example, born in Georgia, inducted at Fort Lewis, Washington. As would be expected, the greatest discrepancy occurred in the Pacific coast induction centers reflecting a westward migration. Movements into adjacent or nearby states could not be detected, but in general these local movements did not involve movements into a different climatic environment to any extent. The various states were not represented equally in the series or even proportionally represented according to their population density. Some of the states with very small representations such as Delaware, Nevada, and Louisiana show divergences in association between temperature and body size that may reflect inadequate sampling.

MEASUREMENTS USED IN THE ANALYSES

In addition to the biographical items of age and state of birth, nude weight and stature were obtained on all subjects. Surface area, based on the formula of DuBois ('36), was calculated for each individual. These calculated surface areas, although of limited accuracy for any one individual, were considered to be much more accurate when expressed as mean values for the 48 state samples. A calculation by state of the average body weight divided by the average surface area was made, but individual determinations of this index for 15,000 men were considered impractical for hand calculation. The state indices based on mean values were considered to be identical with state averages for individual indices. The weight-surface area index favored by Schreider has a good physiological rationale but also a mechanical and statistical disadvantage as presently used. Since the denominator in this index (surface area) is calculated from weight and stature and is merely a function of weight corrected for stature, it cannot be independent of the numerator (weight). The ideal index would consist of weight, or fat-free weight as a better indicator of metabolic mass, divided by an actually measured surface area. There were no data available incorporating these measurements so the present system had to be utilized.

Roberts included as a possible explanation of his observed weight-temperature relationship the advantageous, low ratio of mass to surface area in heat as facilitating maintenance of body heat balance; no mention was made of the opposite effect in cold, i.e., the conservation of body heat through high ratios. Schreider ('51) was convinced that the size-shape relationships are a function of heat stress. He says, ". . . . body mass/body surface ratio tends to decrease in climates which, at least during a part of the year, put a stress on heat-eliminating mechanisms." Both assume that the body shape and size relationship is in response to one of two possible temperature stresses, i.e., heat. Tropic groups and some arctic groups may never be subjected to both heat and cold, but the middle latitude populations are not as clear-cut. In temperate climates characterized by cold winters and hot summers it remains to be demonstrated where the climatic pressure is greatest.

If the heat-generated body response premise is accepted before an analysis of the data, the following rationale may be developed:

(a) In the United States, at least in the last generation, we have had numerous and common methods of ameliorating the effect of winter cold. Central heating, warm clothes, heated automobiles, must reduce the impact to a large degree.

(b) On the other hand, nothing except total air-conditioning, certainly not available to these young men, can eliminate the all-pervading effect of summer heat.

(c) Therefore, heat stress must be the important climatic variable, and the temperature-body build association will be most closely demonstrated if a value which expresses the amount of summer heat stress is correlated with the appropriate biological measurements.

If the hypothesis that we are dealing with heat stress or cold stress, or a combination of both, is accepted, the mean annual temperature becomes an unsatisfactory measure of climate. In many parts of the world it is the best that can be derived, but in the United States it is possible to find other measures of climatic stress which may be more meaningful. Monthly average dry-bulb temperatures by state are available which, when corrected to the so-called ''normal'' temperatures, give cumulative monthly averages over at least the lifetime of the military subjects used in this paper (Nat'l Summary, Climatological Data, '52). The use of state average temperatures admittedly might be a coarse approximation of the varying conditions within each state, but it was not possible to define the residence of the subjects with any greater precision.

The first climatic data which were correlated with body size and shape in this study were neither mean annual nor monthly temperature. Following the rationale of heat stress given above, it appeared obvious that a climatic heat index which included both dry-bulb temperature and relative humidity should give optimal results. Solar radiation and wind speed would have been valuable, but these data were not available. Mean local noon temperature and relative humidity over a 21-year period were available for varying numbers of recording stations within each state (Day, '53). The July recordings of noon temperature and relative humidity were converted into ''effective temperature'' (Yaglou, '27) assuming a constant minimal wind speed, and state averages were derived from the individual stations. There are at least 4 assumptions inherent in the use of ''effective temperature'':

(a) The ''effective temperature'' comfort index was derived from indoor studies on nude and clothed individuals. It must be assumed that this scale is applicable to outdoor activities as well. The effect of differing wind speeds and amount of solar radiation must be considered to be approximately equal among the states or at least relatively unimportant.

(b) It must be assumed that noon climatic conditions are somehow characteristic of the total period of heat stress.

(c) The calculated state averages must be accepted as reasonable overall estimates for each geographical area. This is not an unreasonable assumption for many areas of the central and eastern United States, but the western states, and particularly the Pacific coast, show great differences within each state.

(d) Finally, a differentiation between hot-wet and hot-dry stress will be reflected in closer correspondence to the biological variables than can be shown with a simple indication of dry-bulb temperature.

The use of mean monthly dry-bulb temperatures by state involves fewer but similar assumptions. The state averages must be accepted, and the intra-state dry-bulb differences are even greater than the intra-state range of ''effective'' temperatures. Only two monthly averages are used, January and July, and it must be assumed that each is characteristic of the amount and duration of a climatic stress period. It would be useless to investigate these periods separately if they were perfectly correlated, e.g., cold winters with cool summers and vice versa. The United States January and July mean state temperatures are imperfectly correlated ($r = +.786$) and are therefore considered separately in the succeeding analyses.

The temperature data, size of sample, and biological variables used in the correlation analyses are given in Appendix A.

CORRELATION BETWEEN BODY SIZE AND TEMPERATURE

The statistical association of the 4 biological variables (weight/surface area, weight, surface area, and stature) with 4 estimates of climatic stress are given below in table 1. These correlations are all based on the averages of the 48 state-groups (the District of Columbia is included with Maryland), and therefore have a common *n* of 48. The significance level based on $n - 2 = 46$ is .285 at the 5% level and .368 at the 1% level. The coefficients shown in table 1 can be summarized into a series of general points:

TABLE 1

Correlation coefficients between body size and temperature

	MEAN ANNUAL TEMPERATURE	JULY NOON "EFFECTIVE" TEMPERATURE	MEAN JULY TEMPERATURE	MEAN JANUARY TEMPERATURE
Weight/surface area	—.535	—.404	—.384	—.587
Weight	—.460	—.319	—.310	—.528
Surface area	—.359	—.222	—.223	—.436
Stature	—.044	+.043	+.007	—.111

(a) The raw correlation coefficients are all negative in sign, except for stature in the two summer temperatures. This follows Bergmann's rule of smaller size in higher temperatures and larger size in lower temperatures.

(b) It is possible to compare the association between weight and stature with the results shown by Roberts on a world-wide basis. The coefficients between United States mean annual temperature and these biological measures are lower than Roberts found in his world analysis. His correlation of weight with annual temperature was — .600 and between stature and temperature, — .351. The correlation between stature and weight in this series was also less than Roberts', + .655 for the United States versus + .734 for the world-wide series. The regression of mean weight with temperature showed considerable difference between these series. Roberts' increase in mean weight with a decrease of 1°F. was .305 kg while the United States group showed an increase of only .109 kg. This discrepancy may be caused by the much narrower range of annual temperatures in the United States, 30°F. and 70°F. for Roberts' series. Also, it may represent the presumably more homogeneous nutritional pattern in the United States, or less difference between the average ages of the groups compared.

(c) The most interesting aspect of the correlation coefficients shown here is the possibility of directly comparing the association of 4 measures of body size and/or shape with 4 different sets of temperature data. It is clear that cold stress conditions as indicated by the mean January temperature are most highly correlated with all measures; mean annual temperature ranks second, and the heat stress conditions, as indicated by the July values, show distinctly lower associations. This is in direct contradiction to the theory that the size and shape of men, at least in the United States, are somehow a function of heat stress. It will also be noted that the average "effective" July noon temperature, which includes the relative humidity, is very little better than mean July dry-bulb temperature. This suggests either that a hot-wet, hot-dry response is not present in this series or, if present, it is masked by a poor measure of humidity stress in the analyses.

(d) The ratio of weight to surface area shows a slight advantage in the size of the correlation coefficients regardless of which temperature stress is used. This advantage is small, perhaps because of the interrelationships between these variables since they are both calculated from the same individual data. Its principal advantage at present would seem to lie in being a single value and therefore easier to manipulate than weight and surface area considered separately.

The two sets of temperature which offer the possibility of separating summer and winter stress are expressed as partial coefficients in table 2. The comparison of the size and shape variables with each seasonal stress after the effect of the opposite season has been removed by the use of partial coefficients reinforces the importance of cold stress as an important associated factor. The partial correlation coefficients for mean January temperature with July temperature held constant are only slightly lower than the raw coefficients in table 1, while the July partial coefficients are not statistically significant in table 2.

TABLE 2

Partial correlation coefficients between body size and temperature

	MEAN JANUARY TEMPERATURE (JULY TEMPERATURE HELD CONSTANT)	MEAN JULY TEMPERATURE (JANUARY TEMPERATURE HELD CONSTANT)
Weight/surface area	—.500	+.155
Weight	—.483	+.199
Surface area	—.432	+.214
Stature	—.187	+.152

Another correlative approach has been used in table 3 where multiple correlation coefficients are utilized. Also, the relative contribution of the two independent variables in the multiple regression equations are expressed as a percentage of the explained variance. When weight and stature together or weight and surface area together are correlated with mean January and July temperatures separately, the multiple coefficient is slightly larger than the raw coefficients in table 1. Weight is consistently the more important, especially against the winter temperature stress. When each of the biological variables is correlated with January and July temperatures together, the relative ranking remains similar to the coefficients given in tables 1 and 2, and the multiple coefficients are slightly larger than the mean annual temperature correlation coefficients. Stature remains statistically not significant throughout these analyses, and of the same magnitude that Roberts found with mean annual temperature when the effect of weight is held constant, i.e., + .164. There is a hint in the partial correlation coefficient between stature and July temperature and the relative contributions to the winter and summer temperatures that stature has a small, positive correlation with summer heat stress. This could provide some corroboration for the recent findings of Baker (unpublished) who demonstrated stature to be an important variable in response to desert heat stress in a military series.

TABLE 3

Multiple correlation coefficients between body size and temperature and relative contribution

	COEFFICIENTS	RELATIVE CONTRIBUTION	
		%	
	Weight and stature	Weight	Stature
Mean January temperature	.612	66.0	34.0
Mean July temperature	.416	60.0	40.0
	Weight and surface area	Weight	Surface area
Mean January temperature	.611	58.1	41.9
Mean July temperature	.441	54.8	45.2
	January and July temperatures	January	July
Weight/surface area	.600	78.6	21.4
Weight	.554	73.1	26.9
Surface area	.476	68.7	31.3
Stature	.188	55.3	44.7

DISCUSSION

Since the essence of this paper is environmental determinism, some speculations concerning cause and effect relationships of climate and body size are unavoidable. Four possible explanations of the increase in size in colder climates and vice versa are presented for consideration in the authors' order of increasing probability:

(a) It is possible that the temperature and body size associations are influenced by the non-random distribution of different national extraction groups in the United States. Trite examples such as: English in the South, Germans in Pennsylvania, and Scandinavians in Minnesota will be all too apparent. Two factors argue against the importance of such an explanation. One, most of the states are now thoroughly mixed in the European extraction of their population; and, two, the idea of a carry-over of European body size and temperature relationships presupposes either unproven genetic control or some sort of selective migration by Europeans into familar climatic areas. It is doubtful that any sizable portion of the body size and temperature association can be attributed to national extraction groupings within the United States.

(b) Many readers will have noticed that certain regions of the United States characterized by low body weight and high environmental temperatures are traditionally considered economically depressed. The young men from those areas may have been unable to achieve their ''true'' potential body size because of dietary insufficiency or deficiency. This is a very difficult matter to prove or disprove especially since our so-called economically favored regions contain local depressed areas or urban slums of sizable proportions. No sociological data which would be clearly indicative of past nutritional background for each state were known to us, but an average per capita income for 1950 by state (World Almanac, '54), which might be considered a rough approximation of the desired data, was correlated with the average weights by state in this series. The correlation coefficient was + .251, not significant at the 5% level. The size of this coefficient must have been influenced by the small body weights and low per capita incomes in the South. This is not entirely a fair association since the low income of the southern states is highly influenced by their large Negroid population which is not included in this military series. It would seem fairer to say that the great majority of this series probably had a roughly equal economic opportunity for an adequate nutritional background.

(c) Having disposed of national extraction and nutritional opportunity as improbable causes of the size and climate associations, there remains the question of a homeothermic relationship. This is inherent in the use of the weight/surface area ratio as indicative of a heat conservation mechanism in the cold and heat dissipation mechanism in high temperatures. Such an explanation, favored by Schreider and Roberts, is most attractive when the emphasis is placed on the high surface area per unit of body weight advantage in hot climates. Since the American series used here showed larger correspondence to winter temperatures than to summer climate, it is difficult to accept it as an important causal factor.

(d) A more attractive hypothesis, although admittedly complex, which seems to fit the United States data is as follows. It is well established that cold weather stimulates both appetite and activity, and heat stress has an opposite effect (Bass et al., '53). Also, the combination of expanded appetite and muscular activity in the proper proportions results in an actual increase in the quantity of muscular tissue (proteins and associated fluids) and perhaps bone. If an adequate diet is available throughout the period of growth, it is reasonable to suppose that larger body weights and therefore higher weight-surface area ratios will be found in areas with either a more severe cold stress, or one of longer duration, or both. There well may be other causal factors which operate in the body size and temperature relationships in the United States population, but this is our choice on the basis of available evidence.

After having devoted considerable time and effort to demonstrate the relationship between body size and temperature, it may be wise to point out at least one pitfall of comparing peoples with very different cultural backgrounds. If we accept the heat regulation basis of this relationship and try to apply it to the Eskimo, the picture becomes very confusing. The Eskimo are a good example to use because there has been a tendency to think of them as a prime example of cold conditioning (Coon et al., '50). Roberts included three Eskimo groups and plotted their mean weights and annual temperature. We have recalculated weighted averages for the three groups in both body weight and annual temperature. The weighted average body weight for the 190 Eskimos is 62.9 kg and the annual temperature 29.2°F. The expected mean body weight for this temperature, based on his total series regression equation, is 66.7 kg, a difference of 3.8 kg. This difference may not appear to be very large, but it makes the Eskimo fit his distribution better at a mean annual temperature of over 40°F., comparable to Maine or Minnesota. There is no reason to doubt either his body weight or annual temperature data, but neither is it realistic to think of the Eskimo crouched motionless over a seal hole in the bitter, all-pervasive, arctic cold. A quite different picture of Eskimo environment is shown by the following quotations from Stefansson ('46).

> "When continental Eskimos go inland (in the summer) they meet terrific heat, humid temperatures running toward 100°F. in the shade, with the nights almost as hot as the days, the unsetting sun beating upon them the twenty-four hours through . . . Before white men's influence spread over the North American Arctic, the typical Eskimo house in the afternoon and evening resembled a sweat bath rather than a warm room . . . In the Mackenzie house, then, we used to sit stripped, except for the breeches, from around four in the afternoon, when the outdoor work was done, to around ten or eleven, when it was bedtime. There were streams of perspiration running down our bodies constantly, and the children were occupied in carrying round dippers of ice water from which we drank great quantities."

It appears then that the Eskimo (at least the central groups) are not only exposed to considerable heat stress in the summer which has but slight influence on the mean annual temperature value, but are subjected to an amazing amount of heat stress throughout the winter. Thus, 40°F. may be more representative of their actual annual ambient temperature (including indoors).

SUMMARY

An investigation of possible statistical relationships between climatic environment and body size in a sample of youthful, white, American males was carried out. The series, consisting of approximately 15,000 men measured at the time of their induction into the Army, was divided on the basis of state of birth into 48 groups, and average biological and environmental values for each state were correlated. Body weight and stature were measured on the men and surface area was calculated from these values. The average weight divided by the average surface area for each state was also used. Four measures of climatic environment, mean annual temperature, mean July noon ''effective'' temperature, mean July temperature, and mean January temperature, were analyzed with the measures of body size by the use of correlation coefficients, partial correlation coefficients, and multiple correlation coefficients.

The analyses indicated that there was a correlation which followed Bergmann's rule of larger weights, surface areas, and greater weight per unit of surface area in colder climates. In contrasting the different types of temperature data with the body size it appeared that January temperatures were more closely correlated than the heat stress data or the mean annual temperature. The weight/surface area ratio showed little advantage over a simultaneous analysis of stature and weight by the multiple correlation technique.

Four possible causal factors for the temperature and body size relationships were examined. Regional distribution of groups with common European national extraction, unequal nutritional opportunities caused by economic factors, heat regulation through proportional changes in the heat generating mass and heat dissipating surface, and the stimulation of appetite and activity in cold were discussed; and the last chosen as most plausible with these data.

The study clearly indicated that association between body size and environmental conditions is not restricted to "primitive" groups. The causes for the association (which can only be hazarded here) may not be the same between groups, but neither can the influence of environment on man's physical form over and above his cultural defenses be discounted. The conclusions of this paper are that Bergmann's rule of body size relationship with environmental conditions are valid in a United States population and that this relationship is more highly correlated with January than annual or July temperatures. The reasons why must await further and probably experimental type studies.

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APPENDIX A

Natal state samples used in the statistical analyses

STATE OF BIRTH	NUMBER	AGE		ANNUAL TEMPERATURE (°F.)	JULY TEMPERATURE (°F.)	JANUARY TEMPERATURE (°F.)	STATURE (cm)		WEIGHT (kg)		SURFACE AREA (m^2)		MEAN WEIGHT / MEAN S.A.
		Mean	S.D.	Mean	Mean	Mean	Mean	S.D.	Mean	S.D.	Mean	S.D.	
Alabama	444	19.3	2.2	64	80	47	174.0	6.1	63.61	8.61	1.751	.127	36.33
Arizona	121	19.2	2.7	60	80	40	171.7	6.8	64.50	9.17	1.744	.133	36.98
Arkansas	121	19.8	3.2	61	80	41	174.8	6.5	65.96	9.04	1.784	.131	36.97
California	1,329	19.0	2.1	59	76	44	173.6	7.0	66.38	9.08	1.782	.134	37.25
Colorado	124	20.0	2.7	45	67	23	173.8	6.2	67.38	9.17	1.792	.128	37.60
Connecticut	154	19.5	2.6	49	70	27	172.4	6.1	66.98	10.12	1.775	.139	37.74
Delaware	11	21.4	2.2	55	76	35	170.5	7.6	64.53	11.49	1.743	.168	37.02
Florida	296	19.1	2.3	71	81	59	172.7	6.5	62.86	9.10	1.734	.137	36.25
Georgia	511	19.8	2.8	65	80	48	173.4	5.8	63.75	8.84	1.750	.127	36.43
Idaho	105	19.4	3.1	46	68	24	174.4	5.7	68.10	9.10	1.804	.130	37.75
Illinois	641	19.2	2.3	53	76	28	173.7	6.5	67.04	9.01	1.791	.132	37.43
Indiana	104	19.9	2.3	53	76	29	174.6	6.6	69.26	12.23	1.821	.165	38.03
Iowa	513	21.0	3.0	49	75	20	173.9	6.3	68.29	9.47	1.806	.138	37.81
Kansas	189	20.4	2.8	55	80	30	173.6	6.0	67.78	9.48	1.796	.128	37.74
Kentucky	199	20.2	2.4	57	77	36	173.8	5.9	64.97	7.76	1.769	.120	36.73
Louisiana	27	20.1	3.8	67	82	51	172.0	8.5	66.28	9.61	1.770	.154	37.45
Maine	127	20.0	2.1	43	67	17	174.3	7.0	66.66	9.16	1.790	.145	37.24
Maryland	157	19.3	2.6	54	75	34	173.0	6.3	65.54	10.17	1.768	.139	37.07

Nebraska	261	20.4	2.7	50	75	23	174.7	6.0	67.98	8.26	1.809	.120	37.58
Nevada	16	19.0	2.4	51	74	31	170.2	7.6	61.24	7.41	1.698	.124	36.07
New Hampshire	62	19.0	2.0	44	68	19	172.3	6.6	64.02	6.69	1.745	.105	36.69
New Jersey	365	20.3	2.9	52	74	31	172.8	7.0	66.27	10.48	1.776	.149	37.31
New Mexico	61	18.9	2.0	54	74	34	169.5	7.8	60.71	7.53	1.686	.132	36.01
New York	1,057	19.6	2.9	46	69	23	173.2	6.6	67.00	10.18	1.785	.142	37.54
North Carolina	410	19.6	2.4	59	77	42	173.9	5.7	64.99	9.31	1.770	.132	36.72
North Dakota	175	19.6	2.8	40	70	7	174.3	5.9	67.20	7.46	1.796	.107	37.42
Ohio	591	19.7	2.3	51	74	29	173.6	6.6	67.30	10.47	1.789	.149	37.62
Oklahoma	253	19.0	2.3	61	82	38	174.3	6.0	66.09	8.94	1.785	.130	37.03
Oregon	214	18.8	2.0	49	67	32	174.5	6.3	66.79	7.72	1.793	.124	37.25
Pennsylvania	1,499	19.9	2.6	50	72	29	172.4	6.1	66.06	9.53	1.767	.134	37.39
Rhode Island	97	19.2	2.8	50	70	30	170.8	5.7	64.09	9.06	1.729	.128	37.07
South Carolina	173	19.1	1.9	63	80	46	173.9	5.8	64.67	9.89	1.762	.139	36.70
South Dakota	158	20.5	2.7	46	73	17	174.1	6.5	68.15	9.17	1.807	.136	37.71
Tennessee	546	20.2	2.8	59	78	39	174.5	5.9	65.56	9.21	1.778	.134	36.87
Texas	179	19.6	2.7	65	82	47	173.6	6.7	65.37	7.72	1.768	.118	36.97
Utah	149	19.1	2.0	48	72	25	174.0	5.7	66.90	8.27	1.790	.116	37.37
Vermont	62	20.2	2.7	43	68	18	172.9	6.2	67.53	9.89	1.789	.141	37.75
Virginia	308	19.7	2.6	56	75	37	174.0	5.8	64.89	8.60	1.768	.125	36.70
Washington	270	19.6	2.9	49	67	31	175.0	6.9	67.67	9.38	1.806	.139	37.47
West Virginia	349	20.4	2.7	53	73	33	173.3	6.8	65.26	10.15	1.764	.147	37.00
Wisconsin	306	19.2	2.2	43	70	14	173.4	6.8	67.28	8.75	1.789	.135	37.61
Wyoming	23	19.9	3.2	42	66	19	171.6	5.9	64.00	5.43	1.740	.091	36.78

THE OS INNOMINATUM OF THE RECENT PONGINAE WITH SPECIAL REFERENCE TO THAT OF THE AUSTRALOPITHECINAE

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FOUR FIGURES

In 1950 I published outlines drawn to scale of 10 chimpanzee deciduous canines, taken at random out of a series of 50, in order to provide objective confirmation of a previous statement that the chimpanzee tooth is fundamentally different in shape from that of the Australopithecinae. The outlines also made it clear that the main differences are so pronounced as to be immediately evident on direct visual inspection without the need to restate in statistical terms the fact that they exist. Nevertheless, certain measurements and indices were analyzed statistically, the result of which was to demonstrate that in its general shape the australopithecine deciduous canine is not only well outside the range of variation of the corresponding tooth of Recent large anthropoid apes, but actually falls within the range of variation of *Homo* (Bronowski and Long, '52).

In the present communication, series of outlines, drawn to scale, of the os innominatum of the Ponginae are presented (10 each of the three Recent genera) taken at random out of a total series of 62 adults (gorilla 26, chimpanzee 16, and orang 20). These series at once demonstrate the general shape of the os innominatum in the large apes and the range of its variability (figs. 1, 2, and 3). It is suggested that the series will provide a record of particular value for those who have not at their immediate disposal adequate material for comparative study.

For comparison with the ape series are shown equivalent outlines drawn to scale of three specimens of the australopithecine os innominatum (from Sterkfontein, Swartkrans, and Makapansgat) and one of a Bushwoman. The outlines of the fossil specimens have been made by reference to casts and natural size photographs of the originals. The Sterkfontein specimen (of the right side) is almost complete except for the region of the anterior superior iliac spine. However, Broom ('50) states that this region is preserved in the os innominatum of the left side of the same individual, and he was thus able to reconstruct the right side in conformity with it. This reconstruction of the region of the anterior superior spine is reproduced in the outline in figure 3, no. 2. In the Swartkrans specimen the anterior and posterior extremities of the iliac crest are preserved but the intervening part is missing, and the exact size of the ischial spine is obscured by erosion. The sacral articular surface has not been preserved, but according to Broom and Robinson ('52) the ventral margin of the articulation can be defined and they indicate its position and extent in their illustration of the os innominatum. In the outline in figure 3, no. 3, allowance has been made for a slight distortion by crushing of the acetabulum. The Makapansgat specimen is that of an immature individual and consists of the ilium and the body of the ischium. The ischial spine is missing, and also the greater part of the acetabulum. However, sectors of the latter are present on the iliac and ischial portions of the os innominatum and, since the acetabulum may be assumed to have been approximately circular, these can be placed in position with reasonable accuracy. For comparison with the immature Makapansgat specimen, outlines drawn to scale of the immature os innominatum of a gorilla, orang, and chimpanzee, in which the three components of the bone are still not united, are shown in figure 4. The orang and chimpanzee bones have been taken at random out of a series of 12 bones (orang 6 and chimpanzee 6). The os

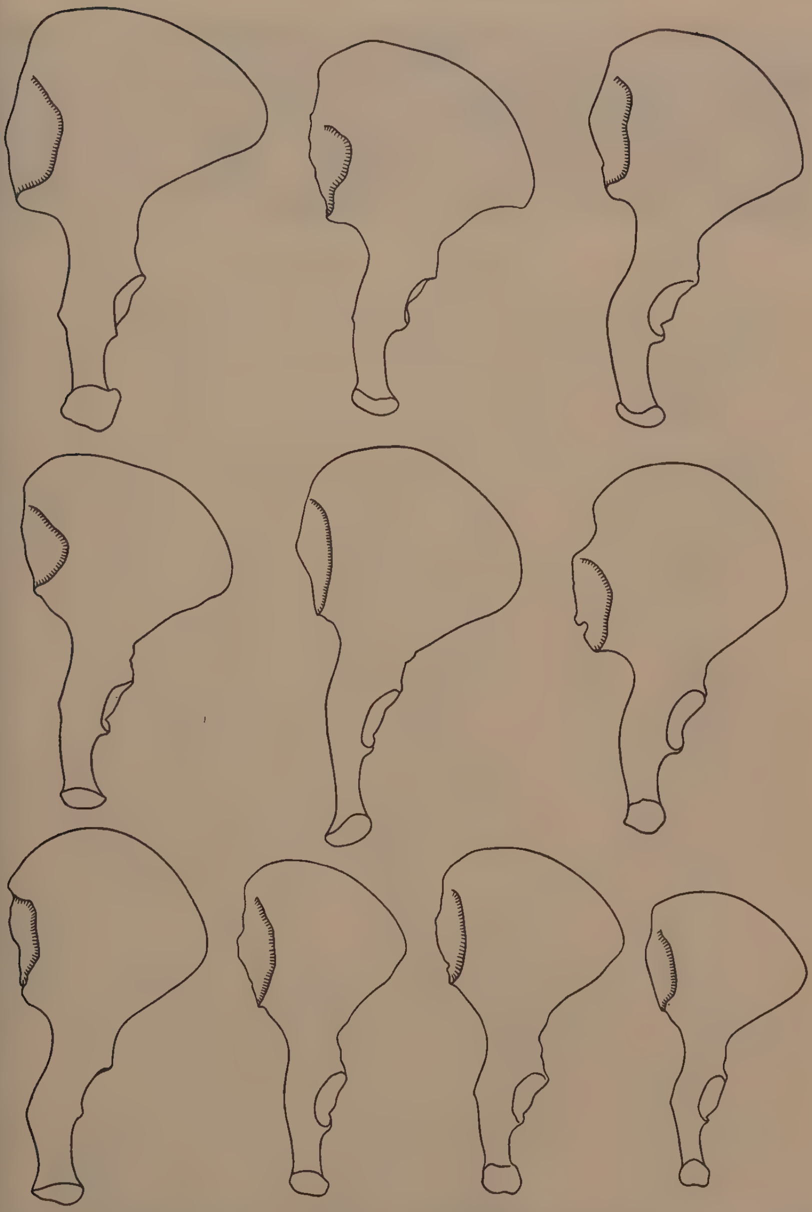

Fig. 1 Outlines drawn to scale of the lateral aspect of the os innominatum of ten adult gorillas, taken at random from a series of twenty-six. In this and the following figures, the ventral margin of the area of sacral contact is represented as projected on the lateral surface of the ilium. × ⅛ nat. size.

innominatum of the young gorilla is the only one available and is less advanced in its development than the other two.

In all cases the os innominatum is viewed from the lateral aspect, orientated in the plane of the dorsum ilii and with the long axis of the body of the ischium vertical. The ventral margin of the area of contact of the sacrum with the ilium is

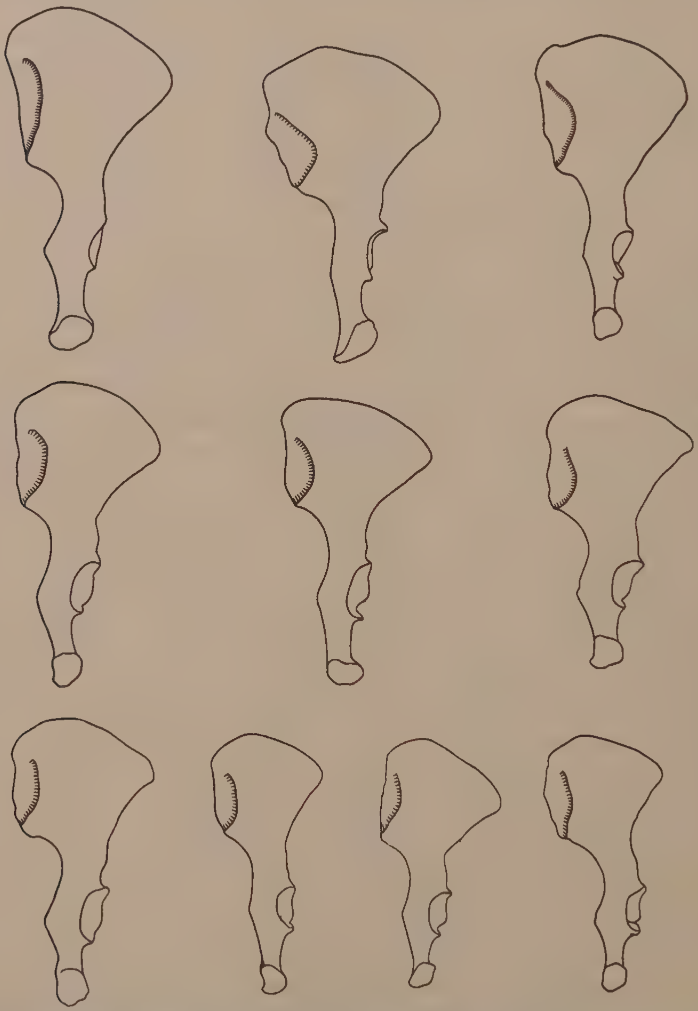

Fig. 2 Outlines drawn to scale of the lateral aspect of the os innominatum of ten adult orangs taken at random from a series of twenty. × ⅛ nat size.

represented as projected on to the lateral aspect. It is to be noted that this area includes not only the actual cartilage-covered auricular surface but a small area of contact above it where the sacrum is directly attached to the ilium by interosseous ligaments. It should also be noted that the sacral

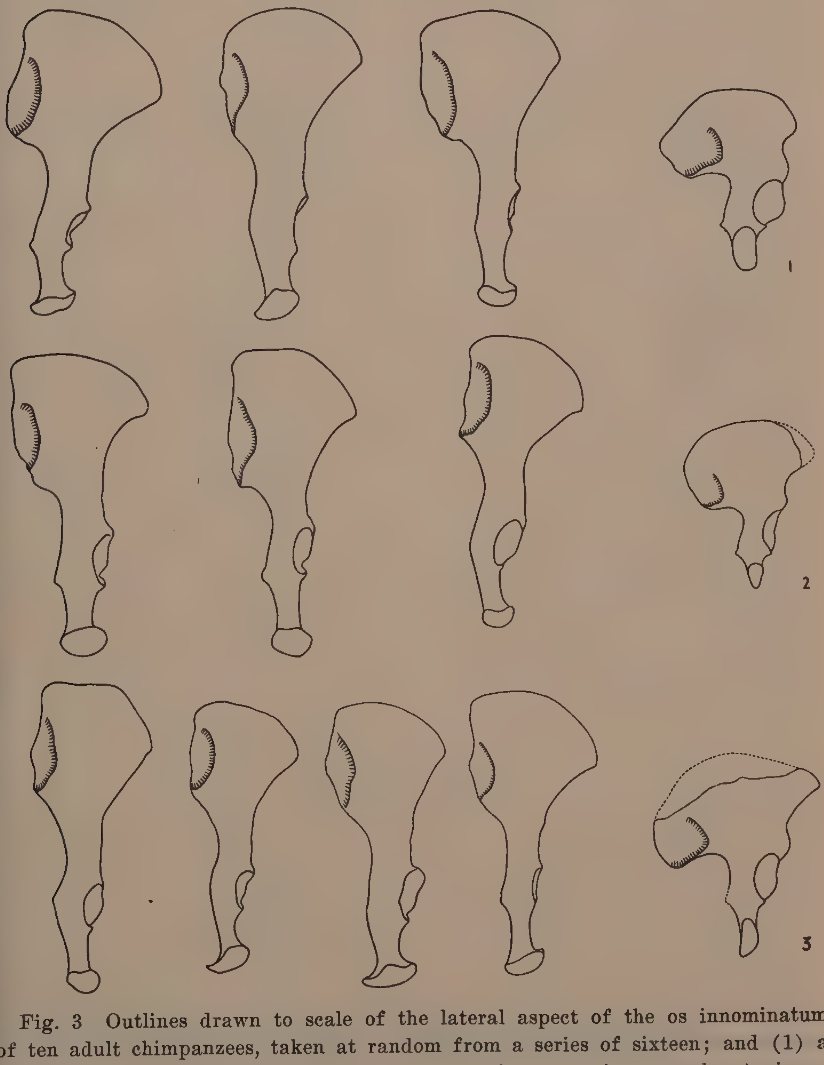

Fig. 3 Outlines drawn to scale of the lateral aspect of the os innominatum of ten adult chimpanzees, taken at random from a series of sixteen; and (1) a bushwoman, (2) Sterkfontein, and (3) the Swartkrans specimen. × ⅙ nat. size.

area as projected appears slightly reduced in size because its plane is set somewhat obliquely to the plane of the dorsum ilii. The ischio-pubic arch is not represented in any of the outlines for the reason that its precise orientation is not known for certain in any of the fossil specimens.

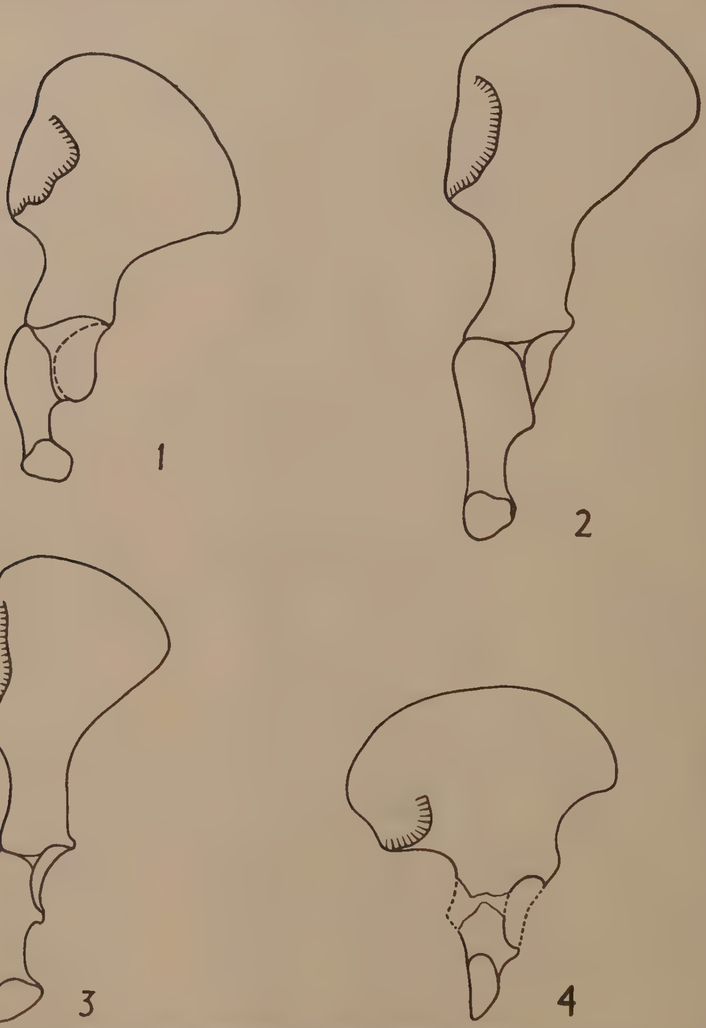

Fig. 4 Outlines drawn to scale of the lateral aspect of the immature os innominatum of (1) gorilla, (2) orang, (3) chimpanzee, and (4) the immature specimen from Makapansgat. × ⅓ nat. size.

As is well known (and as may readily be seen by comparing the outlines of the ape bones with that of the Bushwoman), the os innominatum of *Homo sapiens* contrasts sharply with that of the large apes in a number of quite distinctive features which evidently represent adaptations to the mechanical requirements of an erect bidpedalism (see Weidenreich, '13, v.d. Broek, '14, Waterman, '29, Reynolds, '31 and Washburn, '50). These include (1) the dorsal extension of the dorsum ilii, which brings the gluteus maximus and gluteus medius muscles into a different alignment with the hip joint; (2) the great dorsal extension of the iliac crest, which provides a more extensive attachment for the muscles used in supporting the trunk in the erect posture, and in particular for the powerful sacrospinalis muscle; (3) a rotation of the sacral articulation associated with a reorientation of the sacrum as a whole relatively to the vertical axis of the os innominatum in an upright position; (4) a great reduction in the total relative height of the ilium; (5) the formation of an angulated and relatively deep greater sciatic notch associated with an accentuation of the ischial spine; (6) the development of a conspicuous and stoutly built anterior inferior iliac spine associated with the attachment of the ilio-femoral ligament and the origin of the large rectus muscle; (7) an abbreviation of the body of the ischium with a corresponding approximation of the tuber ischii to the acetabulum; and as a corollary of the previous items (8) a relative approximation of the sacral articular surface to the acetabulum.

The outlines at once make it clear that in this combination of characters the australopithecine os innominatum conforms to the hominid pattern. It also displays certain other features (not shown in the outlines) which (in combination) further emphasize this conformity, such as the sinuosity of the iliac crest as seen from above, some degree of thickening of the ilium in the region of the iliac tubercle, and the pronounced development of the groove for the iliopsoas muscle on its pelvic aspect (particularly evident in the specimens from Swartkrans and Makapansgat).

If the distinctive features of the os innominatum enumerated above are in fact related to the mechanical requirements of posture and gait (and it does not seem possible to suppose otherwise), it may be inferred from the total morphological pattern presented by all these characters in combination (1) that the posture and gait of the Australopithecinae were very different from those of any of the Recent large anthropoid apes, and (2) that the Australopithecinae had acquired the erect posture and gait distinctive of the family Hominidae.

A comparison with the os innominatum of *Homo sapiens* also makes it clear that the australopithecine bone shows certain differences from that of modern man. These differences include the greater ventral extension of the region of the anterior superior iliac spine, the relatively smaller sacral area, and the position of the ischial tuberosity relatively to the acetabulum. As regards the last feature, it may be noted that there is some variation in the australopithecine specimens. In the immature Makapansgat bone, for example, the upper border of the ischial tuberosity is almost level with the lower margin of the acetabulum when orientated with the body of the ischium in a vertical position. In the Sterkfontein specimen it is slightly lower, and in the Swartkrans specimen the level of the upper border of the tuberosity is well below the level of the acetabulum. But if we assume that the three australopithecine bones (which were discovered independently at different sites) represent a random sample, it is evident that in the Australopithecinae the distance between the tuberosity and the acetabulum, relatively to the vertical diameter of the latter, is less than it is in the series of anthropoid apes of which we have records. Even in this respect, therefore, the South African fossils approximate more closely to *Homo sapiens* than do any of the Recent genera of large anthropoid apes.

In some of the features in which the australopithecine os innominatum differs from that of *Homo sapiens* it is clearly more primitive, and it is to be presumed, therefore, that these fossil hominids had not developed the erect posture to the degree of perfection found in modern man.

For assistance in completing the series of ape pelvic bones referred to above, I wish to express my gratitude to the following: Dr. F. C. Frazer, Dr. L. H. Wells, Professors J. S. Baxter, G. Causey, R. G. Harrison, R. D. Lockhart, G. A. G. Mitchell, R. Walmsley, and G. M. Wyburn.

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ON REACTIONS OF PLANT ANTI-N WITH RED CELLS OF CHIMPANZEES AND OTHER ANIMALS

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In the course of studies of chimpanzee red blood cells with antibodies specific for the several human blood factors, there was no difficulty in determining the factors of the ABO system or the factor M. (Data on factors of the Rh-Hr system in chimpanzee red cells will be reported elsewhere.) Of 15 chimpanzees studied, 12 were in group A and three in group O. The presence of the A factor in the chimpanzee red cells was determined by positive reactions with high titered human anti-A, eluates prepared with human anti-A from A_1 blood, and absorbed rabbit immune anti-A (Landsteiner and Miller, '25a). In tests of two group O and 6 group A chimpanzee bloods with an anti-H serum prepared in chickens with secretor saliva and absorbed with A_1B blood, the group O bloods gave distinctly stronger reactions than the group A bloods — a pattern of reactions identical to that shown by human bloods of groups O and A.

Each of the 15 chimpanzee red cells gave strong reactions with several absorbed rabbit anti-M sera. That these reactions were not due to heteroagglutinins was shown by the absence of reactions in tests of the anti-M sera absorbed with human M blood (Landsteiner and Levine, '28). Furthermore, each of three chimpanzee red cells employed removed most of the anti-M activity, but the degree of the absorption as shown by both qualitative and quantitative tests was not as great as that attained by human MN blood.

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[1] The participation in this work by Dr. Ottensooser of the Laboratório Paulista de Biologia, Sao Paulo, was made possible by a grant from the National Research Council of Brazil.

The results of the tests with several anti-N sera, however, were equivocal and in this respect they differed somewhat from the findings of Landsteiner and Levine ('28). Of three anti-N sera studied by the latter workers, one gave distinct to strong reactions on each of the 4 chimpanzee red cells tested, while one was practically inactive and the third serum reacted weakly with only three of the 4 bloods tested. In each case the reactions were controlled by tests of the N sera absorbed with N blood. Wiener ('38) refers to tests of two chimpanzee bloods with 14 different anti-N testing fluids and of these "only one reacted strongly and two moderately, whereas 11 gave little or no reaction." Butts ('53) tested 17 chimpanzee bloods and all were strongly agglutinated by anti-M but not by anti-N sera. It was obvious that the study of the N factor in chimpanzee blood with rabbit anti-N sera was fraught with many technical difficulties and yielded rather inconclusive results (cf. Butts, '53).

Fortunately, another approach was offered by the observation of Ottensooser and Silberschmidt ('53) that a saline extract of seeds of *Vicia graminea* contains a potent agglutinin specific for the human N factor. For the following tests the reagent was prepared by extracting one volume of seeds with 20 volumes of saline for one hour at 37°C. The clear supernatant gave titers of 1:16 on human bloods MN or N, but no reactions on bloods M in tests after incubation for one hour at 37°C. On subsequent centrifugation the titers were 1:64 for MN and N, and only 1:2 for M bloods. The reactions were equally strong with bloods MN and N so that there was no double-dose effect specific for genotype *NN*. At 37°C. the titers were somewhat higher than at 18°C. and the specificity was also more definite.

Of the 13 chimpanzees tested with extracts of *Vicia graminea*, 4 gave reactions of about the same order of magnitude as human bloods MN or N, and 9 failed to react. That these reactions indicate the presence of the N factor is shown by the complete absorption of the antibody by the sensitive red cells of chimpanzee 4 as well as by human bloods MN and N in contrast to the behavior of the red cells of human M and chimpanzees 6 and 8 (table 1). Although no titrations were carried out, the weaker reactions of human MN and chimpanzee 2 with the absorbed plant anti-N as compared with the unabsorbed would suggest that human M and chimpanzees 6 and 8, though inactive or at most very poorly reactive with the unabsorbed extract, may have removed small quantities of the antibody.

TABLE 1

Vicia graminea extract 1:20 was absorbed in a volume of 0.6 ml with 0.3 ml washed sediment of various bloods for one hour at 37°C. The tests were made in small test tubes by mixing one drop of the clear supernatant and two drops of a 2% suspension in saline. Readings after one hour at 37°C.

ABSORBED WITH	TESTED WITH RED CELL SUSPENSIONS							
	Human			Chimpanzee				
	M	MN	N	2	3	4	6	8
Human M	0	++	+++	++	+++	+++	0	0
Human MN	0	0	0	0	0	0	0	0
Human N	0	0	0	0	0	0	0	0
Chimpanzee 4	0	0	0	0	0	0	0	0
Chimpanzee 6	0	++	+++	+++	+++	+++	0	0
Chimpanzee 8	0	++	+++	+++	+++	+++	0	0
Unabsorbed	0	++++	++++	++++	++++	++++	0	0

On the basis of these tests, 9 of the chimpanzees could be classified as M and 4 as MN. This differentiation, however, could not be made in direct tests with available rabbit anti-N sera, and furthermore, both types of chimpanzee bloods failed to remove the activity for human MN or N. As mentioned above, all chimpanzee bloods tested absorbed considerable quantities of rabbit anti-M sera. Apparently, the human and chimpanzee M have more in common than human and chimpanzee N.

A most unexpected result was obtained in the study of eluates prepared from various bloods after incubation for one hour at 37°C. with the plant anti-N. In these experiments, 1 ml of the extract was used for 10 capillary drops of the washed sediment. The exposed red cells were washed 4 times in large volumes of saline and the sediment was then suspended in 0.5 ml saline and heated at 56°C. for 10 minutes. The supernatant eluates were clear and contained only moderate amounts of hemoglobin.

Active eluates specific for the N factor in human or chimpanzee blood were obtained after contact of the extract with human or chimpanzee blood of types MN, and surprisingly enough, also with human or chimpanzee blood of type M, *but not with human blood of type N* (table 2). These paradoxical findings were confirmed in tests of eluates made from several different M and N bloods with identical results.

TABLE 2

Eluates of Vicia graminea

ELUATES FROM	TESTED WITH RED CELL SUSPENSIONS										
	Human			Chimpanzee							
	M	MN	N	1 M	2 MN	3 MN	4 MN	5 M	6 M	7 M	8 M
Human M	0	+++	+++	0	+++	+++	+++	0	0	0	0
Human N	0	0	0	0	0	0	0	0	0	0	0
Chimp 4 MN	0	+±	+±	0	+±	+±	+±	0	0	0	0
Chimp 8 M	0	+±	+±	0	+±	+±	+±	0	0	0	0
Unabsorbed extract	0	++++	++++	0	++++	++++	++++	0	0	0	0

The data presented in table 2 indicate two exceptions to the rules of specificity governing antigen-antibody reactions, i.e. active anti-N eluates from the almost inactive M blood (cf. table 1) and failure to obtain active anti-N eluates from the sensitive and absorbing N blood. Actually M blood did give weak reactions in direct tests with the plant anti-N particularly when the test tubes were centrifuged, and as already mentioned, the findings presented in table 1 suggest that there is slight absorption of anti-N by M cells in contrast to complete absorption by the sensitive N or MN bloods. If the comparatively low degree of absorption of the plant anti-N by M blood is not readily demonstrable under the experimental conditions in table 1, it is definitely established by the strong anti-N activity of eluates prepared from M blood. Perhaps the plant anti-N is loosely bound by M blood and readily released, but to N blood, the antibody is so firmly bound as to resist elution under the usual conditions. This view is supported by the observation that eluates prepared from N stroma at 75°C. for 10 minutes gave weak but distinct reactions specific for N. Under the same conditions, however, eluates from M stroma were inactive.

Possibly the weaker reactions on bloods of type M result from the presence of a species-specific antibody for human blood or an antibody specific for M. In the latter event, the paradoxical affinity of the plant anti-N to M blood may be the combined effect of a weak anti-M linked with the potent anti-N on the same agglutinin molecule. The further investigation of this interesting and unique serological phenomenon will be undertaken as soon as a sufficient supply of *Vicia graminea* becomes available either by shipment from southern Brazil where it is indigenous or by their successful cultivation in the United States.

In order to determine whether other plant agglutinins behave similarly, *Vicia cracca* extract shown by Renkonen ('48) to contain anti-A was studied. This extract gave strong reactions with A, and weak reactions with O bloods. Eluates prepared from A_1 and O bloods, however, behaved as expected from the direct reactions of the extract, i.e. the A_1 eluate reacted strongly with A_1 bloods and weakly with O bloods, while the eluate from O cells reacted very weakly or not at all with A_1 bloods.

Extracts of *Vicia graminea* were also tested with red cells of other species: 5 Java monkeys (Macaca ivus), 4 rabbits, 3 rats, 2 mice, 5 sheep, 3 goats, 5 horses, 5 pigs, 5 cattle and

24 chickens. None of these red cells reacted with the plant anti-N except the horse bloods which gave titers of 1:8–1:16 after centrifugation in contrast to 1:64 for human bloods MN and N. Furthermore, an eluate of plant anti-N from M blood reacted distinctly with each of the horse bloods tested, and an eluate from horse blood gave specific reactions for human N. In one experiment both horse and pig blood removed a good deal of the plant anti-N activity for human N blood.

TABLE 3

Reactions of extract and eluates of Vicia graminea
Summary of several experiments

ELUATES FROM RED CELL OF	TESTED WITH RED CELL SUSPENSIONS							
	M	MN	N	Java monkey	Pig	Goat	Sheep	Horse
Java monkey	0	0	0	0	0	0	0	0
Pig	0	++	++	0	0	0	0	++
Goat	0	+±	+±	0	0	0	0	±
Sheep	0	0	0	0	0	0	0	0
Horse	0	+++	+++	*	*	*	*	+++
Human M	0	+++	+++	*	*	*	*	+++
Extract 1:40	0	++	+++	0	0	0	0	+++

* Not tested.
Reading of tests with eluates were made after centrifugation.

Although pig and goat bloods failed to react directly with the extract, their eluates reacted specifically with human MN and N bloods and with horse bloods. This effect which is stronger with the eluates prepared from pig than from goat blood is analogous to that shown by reactions with, and eluates from, M blood. Eluates from bloods of Java monkeys, cattle, and rabbits were inactive. Some of these observations are summarized in table 3.

These preliminary findings indicate that *Vicia graminea* serves as a most useful reagent for the detection of heterogenetic relationships of animal blood and the human factor N.

DISCUSSION AND SUMMARY

The importance of the naturally occurring anti-N in *Vicia graminea* is illustrated by the ease with which it was possible to differentiate two classes of chimpanzee bloods M and MN. It remains to be seen whether or not the identical differentiation can be made with selected rabbit anti-N. Assuming a continuous supply of blood from a colony of chimpanzees, the production of anti-N in rabbits injected with individual chimpanzee bloods would constitute proof for the presence of the N or at least an agglutinogen related to human N.

A priori, it is not likely that the red cells of all chimpanzees contain both M and N factors and yet the results of tests with the standard method of Landsteiner and Levine ('28) seemed to indicate this uniform behavior (Wiener, '38). Assuming that the genetic mechanism is identical to that in man, the exclusive presence of the heterozygote *MN* in any sizeable population of chimpanzees is excluded because the matings are expected to yield three types of offspring, *MM, MN,* and *NN* in ratios compatible with the Hardy-Weinberg law. Now that two of the three genotypes have been demonstrated, it is quite likely that with more extensive studies, chimpanzees of genotype *NN* will also be found. Such bloods should react with extracts of *Vicia graminea* and fail to react with rabbit anti-M.

Landsteiner and Wiener ('37) have shown that red cells of Old World monkeys, by virtue of their capacity to induce formation of anti-M in rabbits and to react with standard anti-M contain a factor related to human M. Still another relationship of human blood of group B and the *pseudo*-B factor in red cells of New World monkeys and other animals (mouse, rabbit, rat, guinea pig) was demonstrated by Landsteiner and Miller ('25^b) who showed that these otherwise unrelated red cells reacted with eluates prepared from human anti-B and human group B blood, but failed to react with absorbed rabbit immune anti-B sera.

The observations reported on extracts and eluates of the naturally occurring plant anti-N suggest a heterogenetic relationship of a red cell factor of horse to the human N factor and probably also a relationship of pig and goat blood to N. The findings reported on the plant anti-N which under normal conditions cannot be eluted from sensitive N cells but could be eluted from the almost inactive M cells constitute an exception to the rules governing the specificity of antigen-antibody reactions. This new type of immune reaction not observed with other hemagglutinins requires further study.

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DETECTION OF SELECTIVE ADVANTAGES OF THE HETEROZYGOTES IN MAN[1]

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ONE FIGURE

Realization of the preeminent role of natural selection in evolution has been slow. Until recently it was the fashion for physical anthropologists to state that characteristics suitable for the classification of man into races should be non-adaptive, meaning not influenced by selection, and the present author, probably under the influence of Prof. E. A. Hooton, was maintaining in 1940 (Boyd, '40) that the blood groups were suitable for racial classification partly because they were non-adaptive. This point of view has been completely abandoned (Hooton, '46, Boyd, '53). Action of natural selection on the blood groups, suggested as a possibility by Ford in 1945, seems to have been demonstrated by Aird et al. ('54), Pike and Dickens ('54) and Struthers ('51). Ford ('45) and Mourant ('54) suggest that different environments may favor different blood group genes, or at least different proportions of the genes in a population. Mourant ('54) offers some speculations as to the possible mechanisms which might account for this.

Instead of proposing to base physical anthropology upon non-adaptive characters, as did the anthropologists of the last generation, we must inquire into the nature of the evolutionary forces acting to modify or to stabilize in a population the frequencies of the genes which control each character we wish to use.

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We now realize that if a genetically controlled character is found in any considerable frequency in a population, its frequency is being maintained by one or more of the following: (a) repeated mutation at a rate sufficient to compensate for losses such as those due to adverse selection, (b) selection in favor of persons homozygous for the gene, (c) selection in favor of persons heterozygous for the gene. Agencies (b) and (c) could of course sometimes operate together. It has even come to be doubted if agency (a) alone is often the explanation of the existence of any considerable frequency of a gene which has any selective disadvantage.

Fisher ('30) showed that there would be a stable equilibrium ratio of the frequencies p and q of two genes F and G if the heterozygote were better adapted than either of the homozygotes. In fact, if the relative selective advantages of the three genotypes FF, FG, and GG are a, b, and c, this equilibrium is given by

$$p/q = (b - c)/(b - a)$$

From this it is apparent that even a very slight advantage of the heterozygote over the homozygotes would lead to an equilibrium. The equilibrium values of p and q will be equal if $a = c$, and unequal otherwise. Even if a or c equals zero, corresponding to zero selective advantage of one of the homozygotes, an equilibrium will exist, but now p will not equal q. See Silvestroni et al. ('54).

Dobzhansky ('44) has shown that in fact this agency, our mechanism (c), is an important factor in maintaining certain genes in appreciable frequency in Drosophila populations, and Fisher, Ford and Huxley ('39) suggested that the persistence of both the "tasting" and "non-tasting" gene for phenyl-thio-carbamide over periods of time so long that the anthropoid apes and man agree in possessing both, might possibly be attributed to an advantage of the heterozygote over both of the homozygotes. The fact that phenyl-thio-carbamide and other compounds whose taste is controlled by these genes are potent anti-thyroid compounds may have some bearing on this problem, but the exact connection is still unknown.

It has been suggested that a similar but unknown advantage of the heterozygote may explain the persistence of the Rh-negative gene in populations such as Europeans and Americans, in spite of the apparent selective action, due to the occurrence of erythroblastosis, acting to reduce its frequency, and of the Rh-positive genes in the Basques, where the action of selection would be to reduce the frequency of the Rh positive genes (Wiener, '42, Haldane, '42, Fisher, Ford and Huxley, '39).

The demonstration that selective forces are acting on any human characteristic, to alter or to maintain its frequency, has of course far-reaching consequences which affect any conclusions we may draw about racial histories from the study of such a character. In this respect we may regard the blood groups as serving, as they often have before, as pilot characters to the physical anthropologist, who may hope to surmise from the evolutionary forces acting on blood group genes what sort of forces are acting on other human physical characters.

The blood group genes in man determine antigens very similar to substances occurring in anthropoids and even in lower animals (Schiff and Boyd, '42) and blood group determinations on Egyptian mummies (Boyd and Boyd, '37) demonstrate them to have been present and reasonably frequent in the Mediterranean populations 5,000 years ago. These genes are of wide occurrence in the various races of man, and no large human populations exist which do not possess at least two of them (O and A). If it is true that they have been present in the human race for lengths of time much greater than 5,000 years, as seems likely, the question arises, have they been maintained at their present frequencies by some selective advantage, perhaps slight, of the heterozygotes? And may some, at least, of the wide variations in frequencies of these genes observed between different populations be explained by local variations in the magnitude and direction of the selective forces acting? This brings up the problem of the possibility of detecting the existence and operation of this slight advantage (Neel, '54). It does not seem too much to hope that anthropologists will have a prominent part in the collection of suitable evidence.

The statement that a certain type has a selective advantage means that more individuals of this type, relative to others in the population, survive to reproduce (at about the same rate as the others), or, in other words, show greater "fitness," or that individuals of the type have on the average more offspring who reach reproductive age, or both. It will certainly be easier to obtain suitable data to test the former possibility.

In practice it is not easy to measure fitness (Penrose, '49, Silvestroni et al., '54), and about the only way open to us to detect very small differences in fitness will be to look for the survival to a greater (though not necessarily great) age of the type having the selective advantage. The finding of this difference in survival rates will not necessarily prove that the difference in selective advantage exists, but it will at least be a first step.

If the ratio of the type Y to the sum of types not-Y is $y:1$ in the newborn, and $y':1$ in adults, we shall say that the fitness of type Y is equal to y'/y, or that the type Y has $100(y'/y - 1)$ per cent greater fitness than the sum of types not-Y (cf. Allison, '54b).

It is not possible, with present serological techniques at least, to differentiate the heterozygotes AO and BO from the homozygotes AA and BB, but in the MN blood group system this difficulty does not exist, for the heterozygote MN is routinely distinguishable from the homozygotes MN and NN. Consequently, if the frequencies of these genes in human populations are stabilized by selection in favor of the heterozygote, we might be able to detect it directly. We could determine the MN blood groups of persons of different ages, and look for a higher incidence of heterozygotes in the older groups. The simplest procedure would be to separate the material into two groups, young persons, and older persons, and test statistically for the significance of any greater frequency of MN in the older group.

Before undertaking an actual investigation it might pay to inquire how many persons we shall have to examine to detect the effect we are looking for. It is thought that evolution commonly takes place by the slow selection of slightly advantageous traits, and Fisher has shown mathematically that selective advantages of the order of 1% are quite sufficient to bring about regular and progressive evolutionary changes in large populations. Fisher ('30), Haldane ('42) and others who have written on the mathematical theory of natural selection have generally considered selective advantages of the order of 0.1 of 1% (1 in 1000) or, to be generous, 1% (1 in 100) to be typical of the sort of thing to be expected in nature. Speaking of a selective advantage of 0.9%, Haldane ('42) says: ". . . if there is any heterosis effect in the case of the blood group genes, it is certainly far less than this." Could we expect to detect such effects by the examination of the blood groups of large numbers of individuals from a human population?

From the formula given by Fisher ('50) for the calculation of chi-square from four-fold table, which is

$$\chi^2 = \frac{(AD - BC)^2\ (A + B + C + D)}{(A + B)\ (C + D)\ (A + C)\ (B + D)}$$

where A, B, C and D are the 4 observed numbers, it is possible to derive a formula for the number of individuals required to give chi-square of any given value (Brandt). This formula is

$$N = \frac{DS\chi^2}{T^2 f\ (1 - f)}$$

where N is the number of individuals examined, D is the proportion of these falling into one of the experimental categories and S the proportion falling into the alternative category, T is the difference in the proportion of the D class observed between the two groups into which the data are divided, f is the proportion of the total falling into one of these groups, and $1 - f$ the proportion falling into the second group. In our case, D would be the frequency of MN found for the total group, and S the combined frequency of M and N. T would be the difference in the frequency of MN in the older group and the younger group, fN would be the number of individuals in the younger group and $(1 - f)N$ the number in the older group. If $f = 1 - f = 0.5$ (i.e. the two groups are equal), N has its smallest value for any particular D, S and χ^2. This has consequently been assumed in the calculations which follow.

Starting with this formula, and taking χ^2, for $P = 0.05$, $= 3.841$, we may calculate the numbers of individuals we should have to examine to prove that a difference of any stated magnitude in MN frequencies was significant. It is assumed that we test equal numbers of older and younger persons, and that the frequency of the MN class in the younger group is 50%. In actual populations, values not differing much from this value are frequently observed, at least in Europe, Asia, and the U.S.A. The results of such calculations are somewhat surprising. For a test to prove that there was an increase of MN from 50% in the younger group to 51% in the older group would require the testing of 38,400 persons. Even this difference already corresponds to a 4% advantage of the heterozygote. It is clear that we can not easily obtain good MN data on such a number of persons who fall satisfactorily into two different age groups, and who all come from a homogeneous population. The acquisition of suitable data on such large numbers of subjects offers considerable difficulties. It may be doubted if hospital records would be sufficiently accurate for the purpose, but if they were, there would be the difficulty of ascertaining that the younger and older groups were strictly comparable. For instance, the existence in the material of data on infants of a social or racial group having particularly high infant mortality, and which happened to have a different frequency of the blood groups, might seriously affect the results. On the other hand, if we compute for a number of persons which, although large, is within the realm of possibility, say 1500, we shall have to find 55% of MN in the older group for the results to be significant. This corresponds to a 22% greater fitness, and already seems considerably larger than we could reasonably expect.

Actually, even these large figures are not accurate. We have merely determined the number of subjects which would have to be examined, if the selective advantage of the heterozygote were such and such a value, *and our sample happened to reflect this advantage exactly.* Since this calculation makes no allowance for the variations due to random sampling, it is clearly not adequate.

This problem has been treated by Paulson and Wallis (Eisenhart, Hastay and Wallis, '47) and they give a formula which in our notation would be

$$N = 3283 \left[\frac{K_a + K_b}{\arcsin \sqrt{P_s} - \arcsin \sqrt{P_e}} \right]^2$$

where K_a is the normal deviate exceeded with probability a, K_b the normal deviate exceeded with probability b, P_s is the true probability of the "successes" for the standard group and P_e that for the experimental group, and $\arcsin \sqrt{P_s}$ and $\arcsin \sqrt{P_e}$ are the angles (expressed in degrees) whose sines are $\sqrt{P_s}$ and $\sqrt{P_e}$ respectively. Probability a refers to the level of significance required in the test, and b is the probability that the sampling will be such that the numbers observed will not display the real difference which exists between P_s and P_e. If we take both a and b at the usual level of significance, 0.05, from table of the normal error function we find $K_a = K_b = 1.645$. The inverse sines can be found in the tables of the angle transformation of Fisher and Yates ('38) or if greater accuracy is desired, can easily be computed from tables of square roots and trigonometric functions, or tables of logarithms and logarithms of trigonometric functions.

From this formula we find that if $P_s = 50$ and $P_e = 51$, as above, then $N = 108{,}530$, or more than twice as many as calculated by the approximate method used there. The numbers calculated for other differences in the percentage of MN in the older group and in the younger group are shown in the upper curve in figure 1.

Although it is not possible at present to distinguish the heterozygotes AO and BO from the homozygotes AA and BB, this would not necessarily prevent us from applying the same technique to these groups. For in most human populations the frequency of the O gene is such that most of the A and B individuals encountered are heterozygotes. For instance, it may be calculated from the observed frequencies of the blood groups that in our population about 85% of the A's and 95% of the B's are heterozygotes. This means that if there were a selective advantage for the heterozygotes, in the case

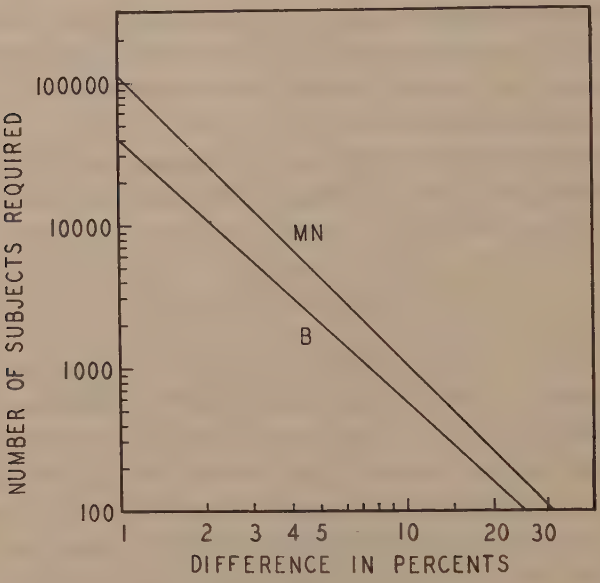

Fig. 1 Graph showing number of persons who would have to be classified as to blood group (MN series, upper curve, ABO series, lower curve) to detect by χ^2 calculations a selective advantage of the heterozygote leading to a difference in the percentage of the heterozygote in older and in younger individuals of the magnitude shown.

of either of these genes, the frequency of the A, or the B, group ought to increase, by and large, as compared to the other blood groups. The possible neutrality or disadvantage of the homozygote AA or BB would have little effect on this over-all picture. Therefore we could test a group of persons subdivided into different age groups just as outlined above for MN. There exist various ways of arranging the data, but the simplest would be to classify each age group into A and not-A or B and not-B. These possibilities will at least suffice to demonstrate the basic principles.

Since group A amounts to less than 50% in our population and group B to still less, we shall find that this makes it more difficult to achieve a significant difference between the two age groups. Taking the case of group B as an extreme example, and assuming it to have an incidence in the younger population of 10%, the percentages of group B we should have to observe in the older group, to produce a significant chi-square, are plotted against the numbers of individuals which would have to be examined (fig. 1, lower curve).

It will be seen that even if 2000 persons were examined, the frequency of B in the older group would have to go up to about 14.7%, which corresponds to a 55% greater fitness. Smaller numbers of persons could only give a significant result if still more improbable changes in B frequency were found.

It would therefore seem that slightly greater fitness of the heterozygotes, of a magnitude which we well suppose to be operating, would be too small to be easily detected by a χ^2 test based on differences in two groups of different ages.

Aird et al. ('54) have made this same point in regard to testing for differences in disease incidence in the various blood groups. They find that a person of blood group O is about 1.35 times as likely to develop peptic ulcer (requiring hospital treatment) as are persons of other blood groups. Yet to produce strong evidence of this would require about 500 patients if the control group were very large, or about 1,000 with a control group of equal size. The smaller, though considerable, association of group A with cancer of the stomach could hardly be established with a number substantially smaller than 2,000 patients.

However, the chi-square test is not the only statistical technique available for treatment of our problem, and under some circumstances is not the most sensitive test for significance. It is possible that other tests might enable us to detect a significant effect with smaller numbers of subjects. For instance, suppose we had obtained the following imaginary data on 1111 subjects, divided into two age groups (table 1).

There is a suggestion of the suspected trend here, but we find that the chi-square for the data is 2.396, which, for one degree of freedom is not significant. If we had been able to arrange the same subjects into several groups according to increasing age, as shown in table 2, we should have found that chi-square was 3.818, but since the number of degrees of freedom is now 4, this is still not significant (chi-square of 9.488 required for significance).

A more sensitive test for significance in such data is the rank t-test (Bross, White, '52, Wilcoxon, '45, Kruskall and Wallis, '52). Computational details will be found in the references given. If we apply this test to the above data, we find

$$t^2 = 3.91$$

Looking up this value in the table of chi-square, we find, for *one degree of freedom*, which is appropriate in this case (Bross, Kruskall and Wallis, '52, White, '52), that the value is significant. Therefore this test would detect the significance of a progressive change with age of the MN frequency of the sort shown in the data of table 2.

The rank t-test is thus seen to be the most appropriate for data of the sort which we might expect to obtain, and of the sort which might conceivably demonstrate the existence of a selective advantage of the heterozygote. A significant result *might* be obtained from a total of about 1000 subjects, in which the frequency of the heterozygote changed from 50% in the youngest group to 59% in the oldest, although from the above we can seen that our sample of 1000 might also easily fail to reflect the (assumed real) advantage of the heterozygote to a significant extent. To make sure of detecting even such a relatively large effect, therefore, considerably larger samples than 1000 should be examined. In any case, however, the rank t-test has the advantage of detecting, not merely, as does chi-square, a disproportion in the subdivision of the various classes, but a trend in some given direction.

TABLE 1

Hypothetical difference in MN frequencies in two different age groups

	AGE GROUP I	AGE GROUP II	TOTAL
MN	240	360	600
M + N	228	283	511
Total	468	643	1111

TABLE 2

Hypothetical differences in MN distribution in five different age groups

	AGE GROUP					
	I	II	III	IV	V	Total
MN	120	120	120	120	120	600
M + N	120	108	103	96	84	511
Total	240	228	223	216	204	1111

However, it will readily be seen that the change indicated by the imaginary data of table 2 is larger than current evolutionary theory would lead us to expect, and would point to a selective advantage, if real, of over 40% for the heterozygote. Smaller changes could be detected if larger numbers of subjects could be examined, but this would present the difficulties discussed above.

It is not surprising, in view of the above calculations, that examination of the data contained in my old note-books, relative to blood group determinations on populations in various parts of the world (cf. Boyd and Boyd, '36, Boyd and Boyd, '38) does not show any significant excess of heterozygotes in the older age groups. Probably our best data were for the

Coptic inhabitants of Assiut, Egypt, where we were able to test an unusual proportion of children. Our total series of Copts for Assiut amounted to 412 individuals, and divided into MN and not-MN as shown in table 3. It is apparent at a glance that the older group does not show any excess of MN; on the contrary the MN in the adults is very slightly, but not significantly, *less* than in the children ($\chi^2 = 0.020$, $p = 0.80$–0.90). In view of the above calculations, it is not surprising that no significant effect was found in such a relatively small series, especially as we did not have adequate information to arrange our data into several age groups, so as to use the rank t-test, and did not test any very young children. It may be doubted, however, if any more extensive data on any other comparably homogeneous population exist at present.

TABLE 3

Heterozygotes and homozygotes in children and adults in Assiut

	CHILDREN	ADULTS	TOTALS
MN	94	129	223
M + N	78	111	189
Totals	172	240	412

Children = individuals less than 12 years of age.

The above considerations show that proof that the frequencies of any particular blood group gene are being maintained by selection acting on some selective advantage enjoyed by the heterozygotes will be difficult to obtain by mere statistical examination of data on persons of different ages. This need not diminish our belief that such a mechanism probably does operate, at least in the case of some blood group genes in some populations. In this connection it is of great interest to consider what seems to be a clear example of the operation of selective advantage of the heterozygotes in man, namely in connection with the conditions sickle-cell trait and sickle-cell anemia. It is estimated that the effective fertility of persons born with sickle-cell anemia (homozygotes) is not over 25% of that of the heterozygote who carries the gene and merely exhibits the sickle-cell trait. There is thus a strong selection against this gene, yet in some African populations as many as 40% of individuals are affected. It can be easily shown that such high frequencies could not be maintained by mutation at any rate which is conceivable, and consequently the only explanation is a balanced polymorphism. The heterozygotes must possess some advantage over the normal homozygote. Recent work of Allison ('54a) seems to show what this advantage is.

Allison found a striking difference in the ease with which normal sickle-cell individuals were infected with *P. falciparum* by mosquito bite. He suggests that the abnormal erythrocyte of the sickle-cell individual is less readily parasitized by *P. falciparum* than are normal erythrocytes. Such individuals may have, therefore, a better chance of living to the age of reproduction, or have more physical vigor, as a consequence, and this might mean that a definite selection was acting to favor the heterozygous individuals in regions where malaria is endemic. Allison points out that in fact the populations with the highest incidence of sickle-cell trait occur in very malarious regions.

In a later paper Allison ('54b) gives figures for the numerical value of the advantage which the heterozygotes for this gene enjoy. He calculated that the heterozygote has a 26% greater fitness than the normal homozygote, or a 32% advantage over both homozygotes considered together. It must be admitted that this is a larger value than would have been anticipated. Yet Allison's calculations show that it makes very good sense.

Detection of a state of balanced polymorphism is relatively easy when, as in this case, one of the homozygotes suffers a serious disadvantage. Nevertheless it is interesting to reflect that this is probably the first case to be demonstrated in man, although numerous examples are known in animals. It is also interesting to consider the numbers of patients which would have to be examined to detect even such a large advantage of the heterozygote, were the disadvantage distributed equally between the two homozygotes ($a = c$ in the case considered on p. 38). From figure 1 we see that to establish a significant change in frequency between newborn and adults, the true value of which is an increase from 33.6 to 40.0%, would require the examination of about 2,000 subjects. Thus even this relatively large difference would not be easy to detect. It may be suspected that the differences in the case of some, at least, of the blood groups are distinctly less than this. This seems to be particularly likely to be the case with the MN blood groups, in view of their rather uniform distribution over most of the world. One suspects, therefore, that new cases of balanced polymorphism in man are likely to be demonstrated indirectly, just as in the case of the sickle-cell trait.

It may be that the selective forces acting on the ABO blood groups are stronger than those acting on the MN system, and the lower incidence of gastric ulcer (Aird et al., '54) in groups A, B, and AB may possibly be a reflection of an advantage in this respect of the heterozygotes AO, BO, and AB over the homozygote O (although the author of a leading article in the British Medical Journal ('54) suggests the possibility of a much more direct connection between gastric disease and the presence or absence of blood group substances). In any case it is perfectly apparent that the selective disadvantage of group O in our population is relatively slight compared to that of an individual with sickle-cell anemia here or anywhere else.

To summarize, although a selective advantage of the heterozygote which tends to preserve a balance of gene frequencies seems almost certainly to be acting in man in one known instance, and probably in numerous other cases, direct demonstration of this by examination of large numbers of subjects will not be easy. New cases of balanced polymorphism in man are more likely to be detected by discovery of some selective disadvantage of individuals homozygous for some gene or genes which are moderately common in certain populations.

SUMMARY

It is pointed out that the frequency of certain genes, including the blood group genes, may be maintained in human populations by natural selection acting to favor individuals carrying the gene in heterozygous condition. Examination of the number of individuals which would have to be examined to give a statistically significant χ^2, however, indicates that it will be difficult to accumulate series large enough to demonstrate any selective advantage of the order of magnitude we consider probable in the light of present mathematical theories of evolution. Model calculations and some typical data are presented.

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A BIOCHEMICAL STUDY OF CHINESE AND CAUCASOIDS[1]

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The study of racial differences has resulted in the discovery of many measures which may be used to characterize human populations. Although very few of these measures are chemical in nature, all genetically controlled differences are ultimately chemical, since the primary action of genes is chemical. It would seem plausible then to expect to find measurable chemical differences among human populations such as are known to exist among individuals (Sutton and Vandenberg, '53; Berry, '53).

Of the chemical substances which might be studied, the amino acids found in urine would seem to offer good chances of finding population differences. Many studies in addition to the two referred to above have dealt with amino acid excretion, and some of them have shown that rather marked individual differences exist (Harris, '53; Ulrich, Schropp, and Martin, '54). Exploratory studies in this laboratory suggested the existence of differences in amino acid excretion between Chinese and Caucasoids. Accordingly, the following study of a larger group of Chinese was carried out, measuring not only the amino acids but also certain other substances in the urine which have been explored in previous studies of biochemical variability.

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PROCEDURE

The Chinese subjects consisted of ten male and eight female residents of Ann Arbor whose ages varied from 20 to 54 years. All of them had been in the United States for at least two years and were living under essentially Western conditions. Although two of them are native Americans, they are of known Chinese extraction. The Caucasoids consisted of sixteen males and thirteen females, ranging in age from 25 to 66 years. They are mostly of Western European origin, although no attempt was made to trace their ancestry. No related individuals were used in either the Chinese or the Caucasoid sample; each of the groups contained several married couples, however.

Measurements were made on first morning urine samples, of which from one to nine were obtained from each individual, the usual number being three. Creatinine was determined by a method similar to that of Bonsnes and Taussky ('45) and uric acid by the paper chromatographic method of Berry ('51). The amino acids, with the exception of histidine, were determined on two-dimensional paper chromatograms with phenol and lutidine as solvents (Berry, Sutton, Cain, and Berry, '51). Measurement of the intensity of the ninhydrin-produced colored spots was done with the reflectance attachment of a Beckman model B spectrophotometer. Histidine was determined by the one-dimensional paper chromatographic method of Cain and Berry ('51). Other substances measured are as yet largely unidentified and hence are designated by their color reactions with diazotized sulfanilic acid (DSA) or bromocresol green (BCG) and by their Rf values in butanol-acetic acid-water (80:20:20). The conditions for these procedures are described in Berry, Sutton, Cain and Berry ('51). For the BCG chromatograms an aliquot of urine containing 40 μg creatinine was used as the test amount and for the DSA chromatograms an aliquot of urine containing 100 μg was used. A quantitative estimate of these substances was made by measuring the area of the spot with a polar planimeter.

TABLE 1

Individual means of urinary constituents

SUBJECT	CREATININE	SPECIFIC GRAVITY	pH	ALANINE	β-AMINOISO-BUTYRIC ACID	GLUTAMIC ACID	GLUTAMINE [1]	GLYCINE	HISTIDINE	LEUCINE [2]	LYSINE	SERINE	TAURINE	THREONINE	TYROSINE	VALINE	URIC ACID	BCG ACID .28	BCG ACID .90	BCG BASIC .32	DSA ORANGE .85	DSA PURPLE .90
	mg/ml	*(−1, × 1000)*		*µmol/g Cr*	*µmol/g Cr*	*µmol/g Cr*	*µmol/g Cr*	*µmol/g Cr*	*mmol/g Cr*	*µmol/g Cr*	*µmol/g Cr*	*µmol/g Cr*	*µmol/g Cr*	*µmol/g Cr*	*µmol/g Cr*	*µmol/g Cr*	*mg/mg Cr*	*in^2/40 µg Cr*	*in^2/40 µg Cr*	*in^2/40 µg Cr*	*in^2/100 µg Cr*	*in^2/100 µg Cr*
Caucasoid females																						
571	1.13	12.68	6.47	99	163	0	158	389	1.0	155	98	181	87	101	0	150	0.3	.00	.51	.50	.65	.27
530	1.39	9.35	5.47	500	0	0	650	1850	NV [3]	0	0	1080	400	260	0	0	NV	NV	NV	NV	NV	NV
578	1.58	11.36	5.54	171	67	11	274	683	0.8	238	112	293	214	219	0	87	0.2	.12	.43	.24	.65	.32
562	1.18	11.42	6.38	194	100	56	275	479	1.2	303	83	186	386	58	59	7	0.4	.12	.61	.34	1.02	.31
526	0.56	21.36	6.25	188	0	13	152	266	1.1	0	0	236	0	0	0	0	0.4	.19	.38	.53	.20	.15
576	2.08	13.09	5.72	417	138	0	502	1770	0.8	454	227	505	415	269	237	144	0.4	.39	.33	.06	.57	.29
509	1.03	15.90	6.12	163	33	15	164	421	1.0	55	273	141	112	46	0	23	0.4	.20	.31	.54	.40	.21
504	1.53	13.93	6.07	349	33	0	384	790	1.9	289	349	515	376	131	17	26	0.6	.05	.21	.54	.00	.06
565	1.53	15.57	5.38	69	0	0	69	163	0.4	0	0	90	111	0	0	0	0.4	.36	.21	.00	.99	.13
505	1.07	16.92	5.87	242	113	4	283	876	1.5	282	142	344	198	122	108	92	0.4	.26	.43	.10	.85	.25
120	1.95	13.63	5.87	109	0	0	87	335	0.6	0	200	221	99	0	0	30	0.5	.26	.15	.24	.29	.22
502	1.28	15.44	5.93	263	177	79	244	379	0.8	279	168	326	232	122	71	107	0.4	.24	.36	.31	.60	.29
528	1.89	11.75	6.16	332	117	6	345	1609	1.0	345	283	311	251	262	133	66	0.4	.18	.32	.25	.59	.23
Caucasoid males																						
527	2.05	10.09	5.63	93	0	0	65	116	0.3	0	0	93	126	0	0	0	0.2	.02	.27	.16	.18	.20
962	1.04	14.12	6.15	101	25	30	99	185	0.7	70	0	127	126	0	0	38	0.3	.10	.25	.25	.35	.18
507	1.45	12.68	6.25	120	89	0	198	317	0.8	184	88	121	130	92	29	20	0.3	.08	.26	.12	.55	.28
375	0.41	23.28	7.14	60	0	24	46	44	NV	0	0	NV	0	0	0	0	0.3	.10	.21	.86	.06	.04
531	2.53	11.10	5.68	84	33	0	85	153	0.4	0	0	125	143	0	0	0	0.2	.05	.41	.47	.72	.20
506	1.32	12.70	6.16	430	33	0	450	684	1.0	25	390	548	193	153	17	17	NV	.07	.25	.35	.68	.27
577	1.56	9.76	5.80	277	171	0	314	753	0.7	394	100	249	428	224	275	62	0.4	.41	.20	.00	.37	.22
564	1.97	12.11	5.71	155	0	0	168	350	0.7	0	46	193	166	35	0	0	0.3	.15	.11	.17	.51	.20
819	1.53	14.39	6.26	162	33	23	217	444	0.6	0	0	302	234	69	0	0	0.4	.05	.26	.40	.38	.26
068	1.07	14.70	6.38	156	120	3	147	211	1.0	136	98	143	219	144	8	49	0.3	.00	.31	.35	.50	.29
105	1.97	11.44	6.10	186	134	6	258	477	0.6	225	166	174	245	181	55	76	0.4	.06	.25	.25	.59	.29
532	0.67	15.12	6.00	48	0	0	67	85	NV	0	0	65	202	0	0	0	0.5	.00	.25	.33	.18	.04
501	2.21	14.28	5.68	202	108	0	288	415	0.7	160	148	239	244	90	113	43	0.3	.05	.31	.30	.71	.22
508	1.64	13.11	5.93	156	79	11	225	378	0.7	253	68	174	198	119	87	123	0.4	.06	.40	.33	.54	.32
561	1.09	16.58	6.15	154	0	45	174	361	1.1	0	162	217	308	42	17	0	0.5	.21	.22	.45	.47	.21
503	2.91	8.48	5.30	435	100	0	455	1240	NV	38	0	905	345	0	0	470	NV	NV	NV	NV	NV	NV
Chinese females																						
618	1.91	10.63	5.81	175	589	0	161	374	0.5	119	40	211	581	42	0	105	0.3	.11	.35	.24	.30	.43
749	1.29	19.38	5.38	429	510	0	853	1189	1.6	318	350	1300	96	413	230	89	0.9	.28	.35	.00	.29	.24
549	0.79	21.39	6.49	371	0	0	197	646	2.5	0	318	NV	175	65	144	0	0.5	.08	.26	.59	1.08	.27
671	1.57	14.86	7.27	838	486	27	643	800	2.0	437	239	490	98	1003	202	66	0.5	.00	.41	.25	.56	.38
669	0.76	14.59	5.60	330	0	0	342	794	1.2	488	600	NV	326	0	126	152	0.9	.24	.21	.00	.47	.16
668	0.93	24.64	5.85	138	95	0	142	303	1.6	69	254	186	147	74	72	19	0.8	.00	.00	.08	.08	.18
748	0.88	20.59	5.61	202	NV	0	288	422	0.6	208	169	314	454	0	72	164	0.8	.13	.32	.00	.56	.26
620	0.92	16.30	5.64	285	697	0	359	307	1.1	459	226	165	243	0	177	132	0.5	.20	.19	.00	.42	.37
Chinese males																						
662	1.29	16.58	5.50	503	190	0	447	475	1.2	508	781	NV	367	238	281	109	1.1	.40	.21	.00	.44	.27
672	2.55	10.42	5.37	187	0	0	213	263	0.7	179	375	NV	299	0	0	0	0.8	.19	.12	.00	.24	.22
667	1.61	12.74	5.53	116	198	0	131	123	1.3	0	81	99	130	0	50	0	0.4	.19	.00	.00	.15	.15
665	1.83	12.07	5.70	167	322	0	192	146	0.9	357	313	NV	207	149	0	0	0.4	.03	.23	.06	.51	.30
619	2.49	9.69	5.71	193	224	0	221	243	0.6	153	200	163	309	114	0	0	0.4	.30	.24	.06	.43	.26
664	1.67	12.22	5.22	1400	50	0	1055	1070	1.8	639	1000	NV	379	790	179	164	0.8	.38	.12	.00	.18	.25
670	1.97	10.16	5.78	263	186	0	234	226	0.6	298	496	NV	335	166	0	34	0.5	.15	.13	.00	.32	.27
684	1.17	16.24	6.89	321	198	38	321	259	1.1	0	300	NV	160	126	110	27	0.9	.04	.00	.64	.45	.17
621	1.70	11.76	5.78	180	100	0	227	325	0.6	278	181	177	456	0	0	0	0.6	.20	.24	.00	.52	.46
550	1.98	13.29	6.41	144	289	8	132	179	0.6	0	100	156	205	42	0	0	0.6	.02	.09	.44	.45	.12

[1] Alanine used for standard.

[2] Leucine and isoleucine are not separated by the techniques used. Both may contribute to the spot designated as leucine.

[3] NV = No value.

EXPERIMENTAL RESULTS

idual means of each measure are presented in table ccording to race and sex. These individual means as the basis for later computations, since the

TABLE 2

ues of various measures for Chinese females, Chinese males, Caucasoid females, and Caucasoid males

	CHINESE FEMALES	CHINESE MALES	CAUCASOID FEMALES	CAUCASOID MALES
	1.13	1.83	1.40	1.59
	1.0178	1.0125	1.0140	1.0134
	5.96	5.79	5.94	6.02
	346	347	238	176
	340	176	72	58
	3.4	4.6	14.2	8.9
	373	317	276	204
	604	331	770	388
	1390	940	1008	715
	262	241	185	93
	275	383	149	79
	444	149	341	245
	265	285	222	207
	200	163	122	72
	128	62	48	38
	91	33	56	56
	0.65	0.65	0.40	0.34
	0.13	0.19	0.20	0.09
	0.26	0.14	0.35	0.26
	0.15	0.12	0.30	0.32
5	0.47	0.37	0.57	0.45
)	0.29	0.25	0.23	0.21

samples differed for each individual. It should at all the measures except pH are expressed as (Cr) ratios, as this has been shown to remove most ts of varying dilutions. Table 2 presents the means asure broken down according to sex and race.

To test the significance of the differences shown in table 2, a two-way analysis of variance for race and sex was performed on each substance using the mean values of the various individuals as replications. Since there were different numbers of individuals in the four categories of race and sex, it was necessary to employ a non-orthogonal analysis as described,

TABLE 3

Values of F for differences between Chinese and Caucasoids, between males and females, and for the interaction between race and sex from factorial analyses of variance for race and sex. The variance between individuals within races and sexes was used as the denominator of the variance ratio in each case.

SUBSTANCE	RACE	SEX	LNTERACTION	DEGREES OF FREEDOM FOR ERROR VARIANCE[1]
Creatinine	0.01	7.76[3]	2.54	43
Specific grav.	2.08	8.65[3]	5.24[2]	43
pH	0.01	0.61	0.80	43
Alanine	4.39[2]	0.21	0.23	43
β-Aminoisobutyric acid	22.60[3]	4.85[3]	3.40	42
Glutamic acid	2.19	0.16	0.41	43
Glutamine	3.11	1.15	0.02	43
Glycine	0.84	7.27[3]	0.20	43
Histidine	5.21[2]	7.84[3]	0.34	39
Leucine	5.02[2]	1.25	0.50	43
Lysine	16.57[3]	0.13	2.85	43
Serine	0.00	3.88	1.08	34
Taurine	2.50	0.00	0.20	43
Threonine	2.12	0.58	0.01	43
Tyrosine	4.74[2]	2.55	1.34	43
Valine	0.06	1.34	1.33	43
Uric acid	29.74[3]	0.31	0.31	40
BCG acid .28	0.38	0.16	5.38[2]	41
BCG acid .90	11.41[3]	10.84[3]	0.26	41
BCG basic .32	8.15[3]	0.01	0.10	41
DSA orange .85	1.52	2.15	0.01	41
DSA purple .90	2.90	0.95	0.22	41

[1] There is always one degree of freedom in the numerator.

[2] Significant at the 5% level.

[3] Significant at the 1% level.

for example, by Kenney and Keeping ('51, pp. 265–267). The variance ratios obtained are shown in table 3. In testing the significance of the race and sex differences, the within-group variances were used in the denominators of the F ratios even in the two cases in which interaction was significant, since the inferences are intended only for the particular races and sexes represented in the data.

It will be noted that the Chinese excreted significantly more alanine, β-aminoisobutyric acid, lysine, leucine, histidine, tyrosine, and uric acid and significantly less of the substances designated BCG basic .32 and BCG acid .90 than did the Caucasoids. Females were found to have a significantly higher specific gravity than the males. In the females the excretion of β-aminoisobutyric acid, glycine, histidine, and BCG acid .90 was significantly greater and that of creatinine significantly less than in males. For specific gravity and BCG acid .28 the interaction between race and sex was significant.

DISCUSSION

Although for most of the measures the difference between the races is not large, in some cases it is highly significant. The causes of such differences are uncertain, but their possible nature is suggested by previous studies. One possibility, of course, is that they reflect genetic differences between the races. Many of the morphological differences between racial groups are obviously genetic, and it is reasonable to suppose that some of the biochemical differences are hereditary also. On the other hand environmental differences between the two races also offer a possible explanation for the racial differences. One would expect the biochemical properties of an organism to be more influenced by environment than perhaps any other group of measures, since all organisms are nutritionally dependent upon their environment. Very likely the true situation is a combination of these two effects since the chemical phenotype results from the inherited biochemical potential plus the available substrate.

Evidence for the role of genetics in biochemical racial differences is furnished for lysine by the observations that lysinuria occurs as a constitutional trait in the cystine-arginine-lysine amino-aciduria (Dent and Harris, '51) and in the condition involving lysine alone (Berry, Cain and Rogers, '51; Ulrich, Schropp and Martin, '54). In the case of β-aminoisobutyric acid, Harris ('53) has reported that the high excretion of this substance can be explained as resulting from a homozygous recessive genotype. The consistently high excretion of lysine or β-aminoisobutyric acid by only certain individuals and under a variety of environments is strong evidence that heredity is very important in determining the excretion of these substances.

That diet also plays an important role in determining the amino acid excretion levels has been shown in a recent experiment in which twelve subjects were studied on their own varied diets and on a uniform diet (Sutton and Clark, '54). It was found that the amino acids most influenced by the change to a uniform diet were ones which show considerable individuality in excretion patterns, and the individuality did not decrease significantly when the subjects consumed identical foods. Lysine was the amino acid showing the greatest effects of diet.

This study does not indicate the relative importance of heredity and environment in producing the observed differences. Inferences can be drawn, however, from the nature of the data. In the case of β-aminoisobutyric acid, Harris ('53) divided the population into two groups on the basis of whether or not the excretion of this substance exceeded that of alanine as measured by the ninhydrin color intensity. He found that excretors continued to be such under a variety of conditions and that different individuals under apparently similar circumstances might vary widely among themselves in their excretion levels. In the study reported here, an attempt was made to express the amount of the amino acid excreted in a more quantitative manner; hence, the subjects have not been separated into "excretors" and "non-excretors." However, in both the Chinese and the Caucasoids, "high" excretors and "low" excretors occur, the difference being the greater number of "high" excretors in the Chinese group. Among the Chinese there were also several married couples of whom only one partner excreted β-aminoisobutyric acid in appreciable quantities, suggesting that diet is not the principal factor affecting the excretion of this substance.

The arguments which have been applied to β-aminoisobutyric acid can also be applied to the other substances showing racial differences, but with the exception of lysine, the other substances have not been sufficiently studied in such a way as to throw light on the relationship of heredity and environment.

From table 3 it may be observed that for some of the measures the differences between the sexes are also significant. The fact that females tend to excrete less creatinine than do males may account in part for the often higher value in females of those measures which involve creatinine in the denominator. The sex differences in excretion of glycine and BCG acid .90 have been observed previously (Sutton and Clark, '54).

Differences in races such as have been described here provide the biologist with another means of understanding the great variability which exists between human populations. The biochemical variability of human beings is an important field in which considerable progress is being made, but the extent to which this variability contributes to racial differences is for the most part unexplored. The possibility that some of the differences can be reduced to different gene frequencies offers hope that increased power can be given to the genetic methods of classifying both individuals and populations.

SUMMARY

The first morning urine samples from eight female and ten male Chinese and from thirteen female and sixteen male Caucasoids were compared for differences in a number of chemical measures, particularly of amino acids. The Chinese were found to excrete significantly more alanine, β-aminoisobutyric acid, lysine, leucine, histidine, tyrosine, and uric acid

than Caucasoids. They excreted less of the substances designated BCG basic .32 and BCG acid .90. In the analysis for sex differences, females were found to have a slightly higher specific gravity than males but a lower creatinine concentration and to excrete more β-aminoisobutyric acid, glycine, histidine, and the substance designated BCG acid .90. The two-way analysis of variance showed significant interaction between race and sex for specific gravity and BCG acid .28.

The relative importance of heredity and environment in contributing to the observed differences was discusssed.

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AUSTRALOPITHECUS PROMETHEUS AND TELANTHROPUS CAPENSIS

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EIGHT FIGURES

In 1949 the late Dr. Robert Broom and Mr. J. T. Robinson (Nature Aug. 20) announced the discovery in the Swartkrans *Paranthropus crassidens* deposit of an almost complete mandible with 5 molar teeth the three left and the last two right, in situ. The mandible and teeth appeared so distinctive from the previously discovered remains of *Paranthropus* and so close to primitive human jaws and teeth that they claimed it to be a new and distinct type of fossil man, which they named *Telanthropus capensis.*

The factors responsible for this decision were as follows: the jaw, in the first place, was smaller than human jaws, though the third molar was said to be not only larger than any other in the series but also larger than in any known man. Secondly, because the jaw was small, the symphysis and body and ramus heights and width were greatly reduced as compared with *Paranthropus* jaws. Finally the teeth were much smaller than other *Paranthropus* teeth, the molar length being 38.4[1] as compared with 51 in *P. crassidens* and 35 in the South African native. The first molar in the *P. crassidens* type is 16 × 14.6 and in *Telanthropus* only 12 × 11; and the cusp arrangement appeared to diverge considerably.

The next year they found (Broom and Robinson, '50a) another right mandibular fragment even more delicate than the corresponding part of the *Telanthropus* mandible and with heavily worn but comparable first and second (12.9 × 12.3) molars in situ. The body was so slender that its width at the first molar is 14.7, while that of Heidelberg man is 18.8 and of the type *P. crassidens* is nearly twice as thick 24.2. At the time they felt themselves "not in a position to discuss the affinities of this jaw or even to say whether it is the same species as the *Telanthropus capensis* jaw"; but when the monograph on the Swartkrans ape-man (Broom and Robinson, '52) was published these two mandibles were grouped together in the chapter on "Human remains associated with the Swartkrans ape-man." In the chapter on the "Dentition of *Telanthropus capensis*" an isolated left lower first premolar 8.6 × 10.3 (*Paranthropus crassidens* 9.3 — 10.3 × 11.2 —12.7: means 9.7 × 11.7) and the proximal extremity of a radius had been added to the previous finds as potential parts of the same genus and species, because they came from the same pocket of breccia, which was believed to be of more recent geological age than the *Paranthropus* deposit.

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[1] To avoid repetition of the symbol "mm," all measurements throughout this article are expressed in millimetres unless otherwise explicitly stated.

Meanwhile the cranio-facial fragment of an adult female *Australopithecus prometheus* at Makapansgat (Dart, '49) had shown that australopithecine upper molars (first 12.5 × 12.8; second 13.0 × 14.0) could lie below the maximal measurements, for most of their dimensions, of Australian aboriginals (first 13.0 × 14.75; second 12.5 × 16.0); so it was known that australopithecine molars might well be within the living human range of variation.

These dental dimensions in my estimation corroborated the view, advocated when the occiput was first discovered (Dart, '48a) "that the whole 'sub-family' of Australopithecinae have nothing more than 'generic' rank, within the 'sub-family' Hominidae," and the statement made later that year, when the adolescent mandible was described (Dart, '48b), that "I have not been able, even asuming a liberal application of the splitting technique, to discover enough divergence anatomically between these 4 creatures (*A. africanus, Plesianthropus, Paranthropus and A. prometheus*) to justify the creation of 4 genera to mark what is, after all, the single protohominid phase of human evolution that they severally depict in contradistinction to the next or Pithecanthropid-Sinanthropid (generic) phase. Clearly, too, if this lumping attitude is a mistaken one, and the australopithecine groups in South Africa must be split into 4 genera, wholesale revision of the dryopithecid genus is an early imperative.''

Broom ('50), however, was not content with the creation of the genera *Plesianthropus* and *Paranthropus;* and proceeded even further to the setting-up of the three sub-families to accommodate the various South African proto-men:

(1) Australopithecinae for
    Australopithecus africanus (from Taungs) and
    Plesianthropus transvaalensis (from Sterkfontein).
(2) Paranthropinae for
    Paranthropus robustus (from Kromdraai)
    Paranthropus crassidens (from Swartkrans).
(3) ? Archanthropinae for
    (*Australopithecus*) *prometheus* (from Makapansgat).

Telanthropus capensis, although already announced, was not placed in this particular list; but should presumably also have been entered under the Archanthropinae, along with *Pithecanthropus* and *Sinanthropus.*

Robinson ('53b) on the other hand, did not subscribe to this sub-family classification and more recently has dissociated himself even from the generic separation of *Plesianthropus* from *Australopithecine* by saying (loc-cit. 492) ''In passing it may be noted that *Plesianthropus* is most probably a synonym of *Australopithecus,* which would then include the specimens from Taungs, Sterkfontein and Makapan.''

He still believes however that ''the specimens from Swartkrans and Kromdraai differ markedly from the others in structure and evolutionary tendencies and separate generic status seems correct in this case.'' In that event classification is left with a sub-family of Australopithecinae (Heberer's Prehomininae) having two genera; viz.,

(1) *Australopithecus africanus* (from Taungs).
Australopithecus transvaalensis (from Sterkfontein).
Australopithecus prometheus (from Makapansgat).
(2) *Paranthropus robustus* (from Kromdraai).
Paranthropus crassidens (from Swartkrans)

and a sub-family of Euhomininae to accommodate *Telanthropus capensis,* along with *Pithecanthropus* and all later human types.

This more recent proposal, curiously enough emanates from the author who (Robinson, '53a) in the early part of the same year had shown, and with good reason that the

(a) *Meganthropus africanus* remains from East Africa are indistinguishable from those of South African australopithecines, especially *Plesianthropus* (syn. *Australopithecus*); and that the
(b) *Meganthropus palaeojavanicus* remains from Java are indistinguishable from those of South African australopithecines, especially *Paranthropus crassidens.*

If these contentions are true, we are called upon to envisage the existence on opposite sides of this Transvaal valley (about 30 miles from Johannesburg but scarcely a half mile from one another) at these two sites, Sterkfontein and Swartkrans, of two distinct genera of man-apes; each genus being distinguishable from the other in this valley but indistinguishable, respectively, the one *Plesianthropus* (syn. *Australopithecus*) from a group of australopithecines (*Meganthropus africanus*) more than 1500 miles away in East Africa; and the other *Paranthropus* from another group of australopithecines (*Meganthropus palaeojavanicus*) about 10,000 miles away in Java by the nearest land route. In addition Swartkrans is supposed to contain together with this widespread *Paranthropus* genus a third *Telanthropus* genus which is "manifestly very closely related to the australopithecines but seems to have already reached the euhominid grade of organisation" (Robinson, '53a, 32).

It would of course be hazardous to regard such a situation as biologically impossible, but it seems more probable that there is a simpler explanation of these wide-ranging australopithecine differences and resemblances in my earlier ('48a and b) suggestion; namely that a single australopithecine genus could provide sufficient species to include all the known South African forms; and assuming Robinson's inclusion of the meganthropine with the australopithecine types is reliable, to include also the East African and Asiatic meganthropine forms.

The more recent discovery of an adult female *Australopithecus prometheus* mandible now lends (Dart, '54) further support to that idea by showing that a relatively small jaw and a reduced dental length (i.e. actually less than in *Sinanthropus*) is not incompatible with a specific australopithecine affiliation. Moreover it shows that, the *Telanthropus capensis* enigma can easily be solved by regarding those mandibular fragments as parts of female members of the *Paranthropus* type.

In this connection it may be recalled (vide Robinson, '53b) that, when the first mandible was discovered by Robinson and regarded by him as human, Broom too was very sceptical; but later he accepted Robinson's diagnosis because of this jaw's supposedly closer resemblances to modern human jaws as compared with the other *Paranthropus* mandibles. This altered opinion appeared to be corroborated when an even more slender mandibular fragment was found later.

Broom's initial doubts were also shared by Le Gros Clark ('50, 105, 257) who dissented absolutely from the claim, because "a similar degree of variation can be demonstrated within the species *Homo sapiens*." He made this statement in a footnote to a paragraph in which he was drawing attention to the variations in the Australopithecinae which "demonstrate that in certain features (particularly the dimensions of the teeth and jaws) the morphological hiatus between the Australopithecinae and some of the known fossil hominids is reduced to insignificant proportions." He recalled the facts: firstly, that the mandible in question, despite its reputed smallness, was comparable in size with the well-known Heidelberg jaw but that the cusp pattern, large molar teeth (particularly the relative size of the third molar), the symphysial contour and the broad ramus showed australopithecine affinities; and secondly that, as he himself had pointed out, the smaller teeth of the (? female) maxilla from Sterkfontein approached very closely indeed those of *Pithecanthropus* in their dimensions.

Straus ('50) also took exception to the stress laid by Broom and Robinson ('49) upon the supposedly "human" type of mylo-hyoid groove present in *Telanthropus,* as compared with the supposedly "simian" type of groove found in *Paranthropus,* as a distinguishing feature between genera.

To meet these criticisms and to add to the mandibular material descriptive of the type a sub-nasal upper facial fragment, which he had subsequently extracted from the same breccia pocket, Robinson ('53b) published the paper on "*Telanthropus* and its significance." Relative to the facial fragment he lays stress on the shortness of the canine socket (*Telanthropus* 19.8 *Paranthropus* 27 Bantu average 17.3) and the greater depth of the *Telanthropus* palate; but the distance from the nasal spine to the alveolar point is the same as in *P. crassidens* 33. Other features of divergence are: firstly, that the planes of the nasal floor and the flattened subnasal region meet approximately at right angles at the clearly defined lower margins of the pyriform aperture in *Telanthropus,* whereas in *P. crassidens* there is no such obvious margin; and secondly, that the insertion of the vomer upon the nasal floor, in consequence, assumes a more posterior, or "human" situation vis-a-vis the nasal spine as compared with *P. crassidens.*

Robinson (op. cit. 460) recognises that "As in the case of the type mandible there may be some who will be inclined to regard this lower facial specimen as an extreme variant" of the *P. crassidens* type. Unfortunately the corresponding portion of the *A. prometheus* adult female cranio-facial fragment (Dart, '49) was damaged. I am therefore limiting the present comparison to the mandible; but submit that, since the mandibular comparison supports Le Gros Clark's (op. cit) belief that the *Telanthropus* specimens are in fact australopithecine, there is nothing sufficiently distinctive in the palate to separate it even specifically from *Paranthropus* much less to divorce it generically or familially from its geological contemporary. Lower facial variations in Bantu and other extant human beings are relatively just as great as those that will be illustrated in the sequel for the mandible.

I am indebted to Mr. Robinson's generosity for unrestricted access to the relevant fragments and I wish to state at the outset that these mandibles, taken by themselves, are so human in appearance that there is little doubt that, found in isolation or in a different context, they might reasonably have been claimed as recent human, especially the second extremely slender fragment, whose equivalent might be found in any large collection of African mandibles. This probability, however, also illustrates incidentally how close the mandibles and dentitions of Australopithecinae are to those of living sapient man. The story of *Plesianthropus* (Broom and Schepers, '46) has already provided an episode corresponding to that now engaging our attention. An isolated third left upper molar tooth from the Sterkfontein deposit, concerning which a comparative odontologist of the calibre of Professor J. C. M. Shaw said "the bias of the evidence is in favour of the tooth being a human tooth," was subsequently demonstrated by Broom to be so similar to the corresponding teeth of *Paranthropus* and *Plesianthropus* (op. cit. 99) that there could be no reasonable doubt that it was rightly included by him with the teeth of the australopithecine characteristic of that deposit. If attention had not been so remotely distracted away from the very human features of the Australopithecinae during the past quarter of a century by individuals, who imagined that some or all of their features could be included within the ranges of living apes, there would have developed a clearer understanding of their features that lie within the ranges of sapient mankind. It is part of the purpose of this article to repair part of that deficiency in respect of the mandible.

The lesson that Sterkfontein inculcated was that, although individual fragments in these australopithecine deposits might simulate the sapient human type, we are not entitled to diagnose them as belonging to creatures more advanced in the direction of sapient humanity than are the Australopithecinae characteristic of that deposit, until we have considerably more evidence (not only dental and osteological but also implemental) than we have at present of such contemporary existence of types more advanced towards modern humanity than are the Australopithecinae themselves. Or, to express the same concept alternatively, as long as such fragments can reasonably be assigned to the australopithecine type characteristic of the same or a neighbouring deposit, it is unjustifiable to create another group supposedly more advanced in the direction of sapient man than are the Australopithecinae themselves.

First of all, moreover, we need to know what is the range of variation in the living species of man so as to have some means of assessing the probable ranges of variation in extinct species of mankind. I stressed this matter at the Viking (Wenner-Gren) Foundation Meeting 1949, when I showed that the pelvis of an adult female Pygmy from the Makerere College collection resembled the pelvis of the adolescent *A. prometheus* more closely than any other human pelvis known to me.

In an informative article Professor A. N. Burkitt, just over a quarter of a century ago, compared the Heidelberg mandible and dental arcade with those of a New Caledonian native and an Australian aboriginal respectively. He pointed out that Sarasin's (Atlas für Anthropologie der Neu-Caledonier und Loyalty-Insulaner '22) tables had already demonstrated "that in practically all measurements, individual mandibles of New Caledonians or Loyalty Islanders frequently approach or even exceed in size and proportion those of the Heidelberg jaw. For example, the intercondylar breadth in 5 male New Caledonian skulls exceeded that of the Heidelberg jaw; the same was true of the intergonial breadth."

The outstanding characteristics of the Heidelberg jaw are its chinlessness and the width of its ramus. Yet in two cases, a New Caledonian and a Loyalty Islander, the rami of recent mandibles approach to within two or three the Heidelberg ramus width. Burkitt also drew attention to Thomson's ('15) paper in which there was illustrated a New Caledonian mandible, which was almost as chinless as the Heidelberg mandible; and Burkitt rightly concluded that in its "important characters, namely the absolute size, the general type of the tooth arch, the size and shape of the ramus, and the shape of the chin, parallels can be found in living races of mankind, and the possessor of the Heidelberg jaw."

We do not try to postulate from the presence of mandibles simulating the Heidelberg mandible amongst New Caledonians that another species of mankind, *Homo heidelbergensis* is still extant in the Pacific Islands; but we can demonstrate by comparing such unusual, recent mandibles with the mandibles of other living races the wide range of variation that is exhibited by the lower jaws of the single species of living human beings (see fig. 8 and table 1). Similarly at Swartkrans, or Sterkfontein, or Makapansgat we should not assume that bones or teeth, looking like sapient human bones and teeth must of necessity be the bones and teeth of creatures more human than are the man-like Australopithecinae found in the same deposit! We ought first to furnish overwhelming proof that those bones and teeth could not possibly belong to the very man-like type of australopithecine creatures known to be characteristic of that deposit.

This order of procedure is now seen to have been one that would have been particularly advisable when, as at Swartkrans, Broom and Robinson ('50b) also felt impelled to describe *Paranthropus crassidens* as "One of the earliest types of man." These later discoveries included infant, adult female, and adult male *Paranthropus crassidens* skulls with brain capacities estimated to range beyond previous "anthropoidal" figures for *Paranthropus* to such "human" figures as from 750 cm^3 in the infant, through 800 cm^3 in the adult female to 1000–1100 cm^3 in the adult male. Having claimed then that "with a brain well within the human range it seems impossible to deny human status to the Swartkrans ape-man'' it would have been reasonable for them to have admitted a potentially greater range of variation also in *Paranthropus* mandibles than they had previously envisaged and to have accepted the ''human'' features already encountered in *Telanthropus capensis* fragments, like the ''human'' brain capacities, as further corroboration of that fundamental claim of humanity for *Paranthropus;* instead of claiming, as in point of fact they were now claiming — without expressly stating the claim in so many words — that they had succeeded in isolating from one another two different genera of well-advanced mankind in one and the same geological stratum.

They had also imagined at the outset that *Paranthropus* and *Telanthropus* were separated geologically; but Robinson ('53, 449) states ''there is manifestly no case for an age difference between the ape-man (*Paranthropus crassidens*) and the *Telanthropus* specimens'' and (op. cit. 451) ''it seems to be quite close to Sterkfontein in age.'' In that event we are asked to envisage a situation which to me, is even less probable: the contemporaneity in the same valley of three different hominid genera (or sub-families).

MANDIBULAR COMPARISONS

It is not in dispute that the so-called *Telanthropus* mandible is notable for the lowness of its body but it is doubtful whether the ramus is quite as low as Broom and Robinson ('52) made it. However, we must employ for the purpose of our present comparisons their reconstruction of the ramus (see fig. 1).

In the first text figure are superimposed the profile contours of the mandible (in norma lateralis on the alveolar horizontal and the lacteonic coronal planes) of the adult female *Australopithecus prometheus* (heavy continuous line) of a typical Swedish European male of the Middle Ages (dotted interrupted line: after Bergman, Gejvall and Hjortsjö, '53 plate 2, fig. 1) of *Telanthropus capensis* (dotted line), the large male *Paranthropus crassidens* (light continuous line), and the reputedly female *Paranthropus crassidens* (interrupted line) as taken from Broom and Robinson ('52 figs. 55, 4 and 16 respectively).

This figure shows that there is no great difference between the lower jaw of a Nordic European male and an adult female *Australopithecus prometheus.* They have practically the same supra-alveolar ramus height; but while the australopithecine ramus is slightly shorter and broader in general form the European ramus is longer and slightly more slender. The European jaw has a somewhat higher body and a chin, while the australopithecine jaws are all chinless; but it is obvious that of all these australopithecine mandibles the one that approaches the European most nearly in its general form and body proportions is *Australopithecus prometheus*!

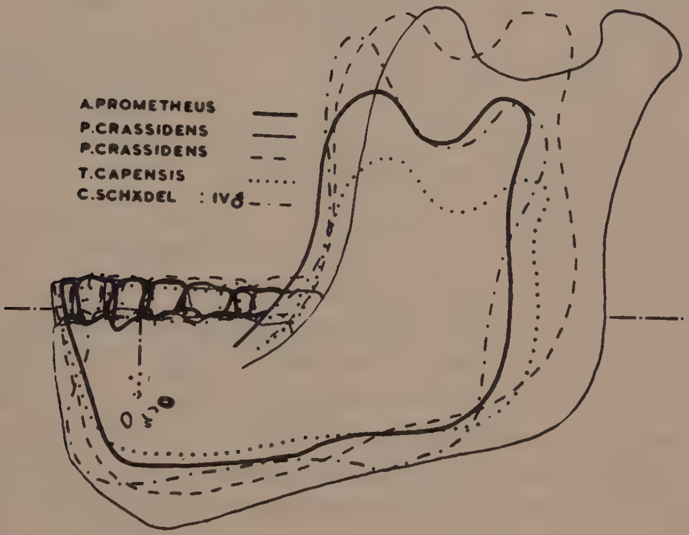

Fig. 1 Profile contours of mandibles in norma lateralis on the alveolar horizontal, and the lacteonic (anterior margin of first permanent molar) coronal planes of *Australopithecus prometheus* (heavy continuous line); a Swedish European male (dotted interrupted line); *Telanthropus capensis* (dotted line); a reputedly female *Paranthropus crassidens* (interrupted line) and the huge male *Paranthropus crassidens* (light continuous line).

It is also apparent from this figure that the smallness of the *Telanthropus* mandible and its symphysis, body and ramus heights, although reduced as compared with *Paranthropus* jaws, are very little reduced as compared with the female *A. prometheus* jaw. Further, it is far from necessary for a mandible to be reduced to the size of a *Telanthropus,* or an *A. prometheus* jaw to fall within the range of extant human size. The 4 australopithecine mandibles represented here vary considerably in the proportions of their several parts; *Australopithecus prometheus* has a much lower body than either the large male or the reputed female *Paranthropus crassidens;* it is not quite as low as that of *Telanthropus capensis,* but it is considerably lower than that of this European Swedish male of the Middle Ages.

On the other hand the length of the *Telanthropus* mandible is considerably greater than that of *A. prometheus* or the European male and its ramus is just as wide as that of *A. prometheus.* The ramus of *Telanthropus* may not have been as high as that of *A. prometheus* but the height of the rami of the large male, and of the reputedly female *Paranthropus* both exceed the height of the *A. prometheus* ramus by an interval greater than that by which the *A. prometheus* ramus exceeds that of *Telanthropus* as restored by these authors. Further, the *Telanthropus* body and ramus heights depart further from those of the European Swedish male than do those of *A. prometheus;* so this greatly reduced ramus height may be held to argue as much against as for its humanity.

Except for this reduced height of the body and ramus in *Telanthropus,* it would be reasonable to state that there is a greater difference between *Paranthropus* and *A. prometheus* than between *Paranthropus* and *Telanthropus.* It is doubtful also whether the supra-alveolar height in *Telanthropus* is as short as it has been represented i.e. shorter by about half a centimetre even than in many sapient human beings (see table 1). In any event there is a great range of variation in ramus height as well as in other features in human beings, whether

TABLE 1

Table of comparative profile measurements of extant and extinct human mandibles

	EXTANT HUMAN GROUP						EXTINCT HUMAN GROUP						RANGES	
TYPES	BUSH FEMALE A. 43	AKKA PYGMY	CHINESE MALE A. 997	SCOTTISH MALE A. 106	LOYALTY ISLAND (Australian)	SHANGAAN MALE A. 1199	SINANTHROPUS FEMALE	HEIDELBERG	AUSTRALOPITHECUS PROMETHEUS	TELANTHROPUS CAPENSIS	PARANTHROPUS CRASSIDENS FEMALE	PARANTHROPUS CRASSIDENS MALE	HOMO SAPIENS RANGE OF VARIATION	EARLY HUMAN RANGE OF VARIATION
Maximum length	88	93	112	120	130	135	110	128	118	111	141	162	88–135 47	110–162 52
Supra-alveolar height	19	28	35	47	32	35	35	42	48	30	68	68	19–47 28	30–68 38
Maximular length (in alveolar plane)	69	68	76	77	107	99	92	112	97	105	110	120	68–107 39	97–120 38
Minimum ramus breadth	30	31	33	31	50	40	39	53	42	45	49	56	30–50 20	39–56 17

we compare the various extinct human types, such as Heidelberg and Peking Man with Rhodesian Man and Palestinian (Skhul) Man; or the living races, such as the Bushman or Pygmy with the Mongolian, Australian and European men (vide Dart, '54a and b). Hence, if *Telanthropus* is to be called human in having a reduced ramus height, so too is *A. prometheus,* since the height of its ramus is not greater than that of many recent Europeans.

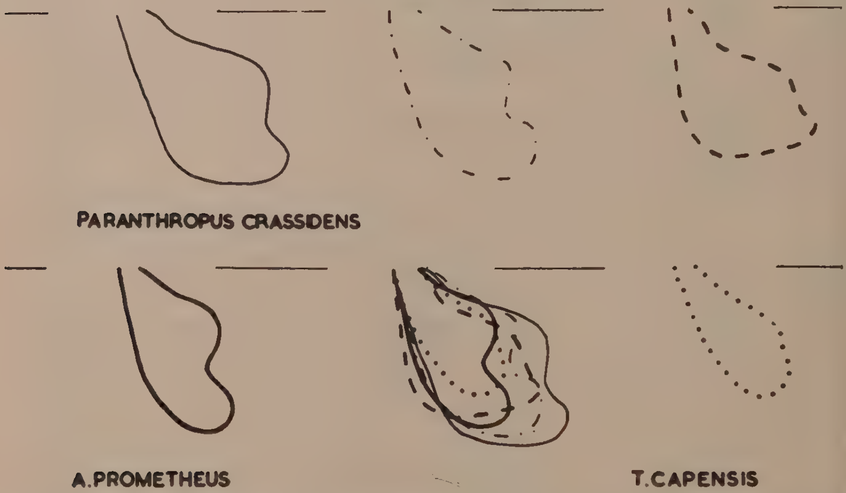

Fig. 2 Australopithecine sagittal symphysial sections of mandibles: the huge male *Paranthropus crassidens* (upper left: light continuous line), the reputedly female *Paranthropus crassidens* (upper centre: dotted interrupted line), a second female *Paranthropus crassidens* (upper right: interrupted line), the *Australopithecus prometheus* female (lower left: heavy continuous line) and *Telanthropus capensis* (lower right: dotted line). All five are superimposed in the centre below to show their comparability despite the range of variation they present.

''In *Telanthropus* the maximum antero-posterior diameter of the symphysis is 16.0 mm while in *P. crassidens* it is 24.5 mm in SK. 23 and 27.8 in SK. 12''(Robinson, '53). In our second text figure (see fig. 2) there have been assembled sagittal sections through symphyses of *Paranthropus crassidens* (as depicted in figs. 5, 17 and 21 respectively from Broom and Robinson, '52) in the upper row; in the lower row are the sections through the symphyses of *A. prometheus* (left lower) and *Telanthropus* (right lower after figure 56, from Broom and Robinson, '52) while in the middle all 5 are seen superimposed. From this diagram it is obvious that there is a wide range of form and measurement variation in the symphyses of what have been admitted by Broom and Robinson as examples of *Paranthropus;* and that, while its symphysis is smaller than those of the others, *Telanthropus* corresponds in shape reasonably with its australopithecine associates. If comparison be made of this figure with the median sagittal sections of mandibles of *Homo sapiens* published by Thomson ('15) it will be seen that there is a much greater range of variation in symphysial form among living human beings than there is in this series of australopithecine types.

In the third, 4th and 5th text figures several series of sagittal symphysial sections have been drawn individually and in superimposition for comparison and contrast with figure 2.

In figure 3 is a series of *Homo sapiens* sections viz., a Nordic Scotsman A.106[2] (heavy continuous line: upper left) of a Southern Kalahari Bush female *keri-keri* (Dart, '37) A.43 (light continuous line: lower left), an indentured male Chinese mine labourer (vide Dart, '52) exhumed at Germiston on the Witwatersrand A. 997 (dotted line: upper centre), a Boskopoid Shangaan male A. 1199 (dotted interrupted line: upper right) and a Pygmoid Zulu female A. 617 (interrupted line: lower right). In the middle of the lower row, all 5 are seen superimposed. Clearly symphysial structure is more variable in the various races of the single species of *Homo sapiens* than in the several known australopithecine species (or genera). The profile contours of some of these specimens are to be seen in figure 6 and others in figure 8.

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[2] The A-numbers cited refer to specimens in the anthropological collection of the Department of Anatomy in the University of the Witwatersrand.

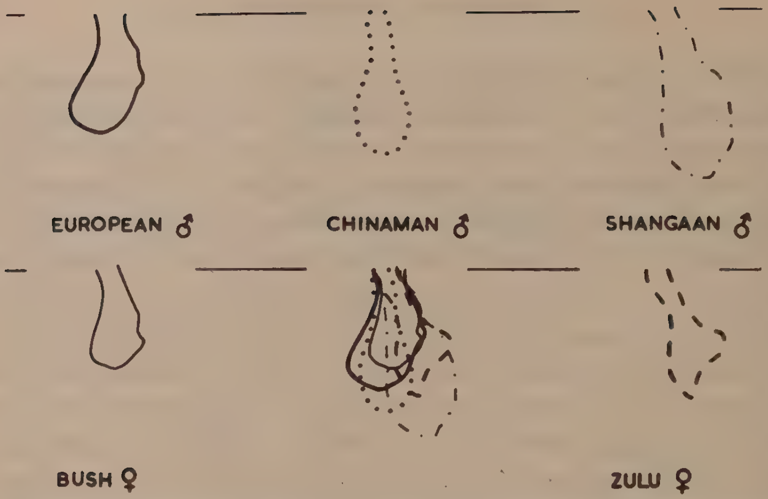

Fig. 3 Sapient sagittal symphysial sections of mandibles: Nordic Scotsman A. 106 (upper left: heavy continous line), Bush female *keri-keri* A. 43 (lower left: light continuous line), Chinese male A. 997 (upper centre: dotted line), Boskopoid Shangaan male A. 1199 (dotted interrupted line), Pygmoid Zulu female A. 617 (interrupted line). All five are superimposed in the centre below to show their great variability despite their belonging to a single species.

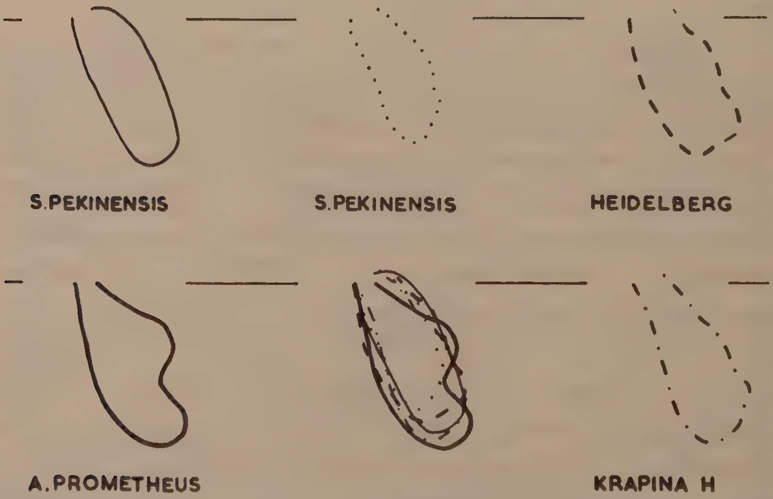

Fig. 4 Early human sagittal symphysial sections of mandibles: *Sinanthropus perkinensis* male (upper left: light continuous line), *Sinanthropus pekinensis* female (upper centre: dotted line), *Homo heidelbergensis* (upper right: interrupted line), *Australopithecus prometheus* female (lower left: heavy continuous line), *Homo neanderthalensis*, Krapina H (lower right: dotted interrupted line). All five are superimposed in the centre below to show that the *A. prometheus* contour blends with the others into a highly harmonious series. (All except *A. prometheus* taken from Weidenreich 1936.)

In figure 4 the series of sagittal symphysial sections include the *Sinanthropus* male (light continuous line: upper left), *Sinanthropus* female (dotted line: upper centre), and *Homo heidelbergensis* (interrupted line: upper right) *Australopithecus prometheus* female (heavy continuous line: lower left) and the *Homo neanderthalensis* Krapina H (dotted interrupted line: lower right). These primitive human outlines with the exception of *A. prometheus* have been taken from Weidenreich ('36); they are all superimposed in the middle of the lower row where the *A. prometheus* contour is seen to blend with them to form an even more harmonious series than it does with the australopithecine series in figure 2.

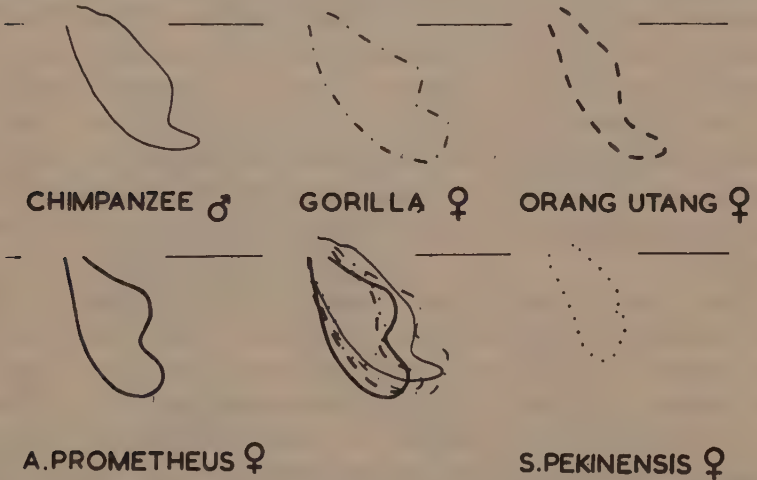

Fig. 5 Australopithecine and extant anthropoid sagittal symphysial sections of mandibles. Chimpanzee male (upper left: continuous line), Gorilla female (upper centre dotted interrupted line), Orang female (upper right: interrupted line), *Australopithecus prometheus* female (lower left: heavy continuous line), *S. pekinensis* ♀ (lower right: dotted line). All five are superimposed in the centre below in order to show the comparability of the gorilla female with the australopithecine female contours and the diversity of contour exhibited by the living anthropoids.

In figure 5 for contrast Weidenreich's ('36) series of anthropoid symphysial sagittal sections has been used. A chimpanzee male (light continuous line: upper left), a gorilla female (dotted interrupted line: upper centre), and an orang female (interrupted line: upper right) are superimposed in the lower row centre on the *A. prometheus* female (heavy continuous line: lower left) and the *Sinanthropus* female (dotted line: lower right). This female gorilla has a symphysial sectional contour which resembles appreciably that of *A. prometheus* and the other more massive australopithecine symphyses. The series as a whole exhibits, however, no wider range of variation relatively than does the *Homo sapiens* series; so it would be a dubious procedure to base any far-reaching conclusions upon the type of symphysial sagittal contour exhibited by *Telanthropus* beyond stating that its form is intermediate between that of the females of *A. prometheus* and *Sinanthropus* and can therefore be logically regarded as consistent with other australopithecine symphysial contours.

When considering the wide range of variation in the profiles of australopithecine jaws, sight can easily be lost of the wide range of variation in form and size presented even by the profiles of South African Bantu mandibles alone. There has therefore been assembled in the 6th text figure (see fig. 6) and oriented in the same manner the profile contours of the Pygmoid (or Bush) type of mandible found in a Zulu female A. 617 (dotted line) and the Boskopoid (or even Rhodesioid) type mandible found in a Shangaan male A. 1199 (interrupted line). These recent Bantu mandibles have been superimposed for contrast upon the contours of the Heidelberg (light continuous line) and the male *Sinanthropus* (heavy continuous line) mandibles.

It is apparent that there is relatively a wider morphological gap between these two sapient human, Zulu and Shangaan mandibles than there is between the *Sinanthropus* and Heidelberg mandibles or between the *A. prometheus* and *Telanthropus* mandibles; and there is a much greater gap still between those of the Pygmoid Zulu and of *Homo heidelbergensis* (or of *Sinanthropus*). There is relatively just as wide a gap between the Zulu and Heidelberg lower jaws as there is between those of *A. prometheus* and *Paranthropus crassidens* but we do not separate the Zulu, a member of the species *Homo sapiens*, from Heidelberg Man, a member of the supposed species, *Homo heidelbergensis*, generically.

This 6th figure illustrates how within two adjacent Bantu tribes living in South Africa today there are encountered mandibles male and female that differ from one another in size, shape and symphysial contour more than do these mandibles from Heidelberg and Peking. They differ as much as do the lower jaws of an *A. prometheus* female and a European male. Until we can find in our primitive human fossil mandibles disparities not merely comparable with but far greater than those exhibited by the living Bush (or Pygmy), Boskop, Mongolian, European and Australian races, it is illogical to create from mandibles different *races* of human beings, irrespective of creating different species, genera or subfamilies.

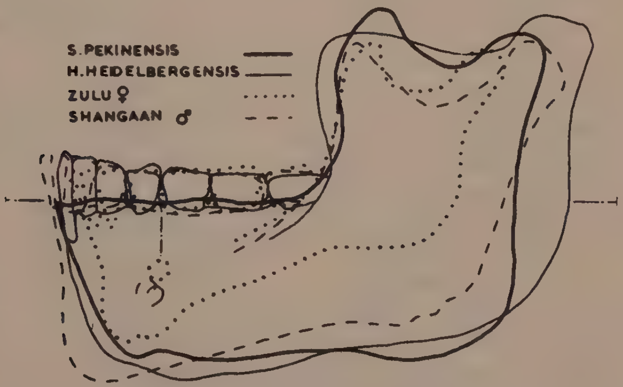

Fig. 6 Profile contours of mandibles in norma lateralis on the alveolar horizontal and the lacteonic coronal planes of a Pygmoid Zulu female A. 617 (dotted line), a Boskopoid Shangaan male A. 1199 (interrupted line), the *Sinanthropus* male (heavy continuous line) and *Homo heidelbergensis* (light continuous line) to show that there is greater divergence in size and form between these two mandibles of *Homo sapiens* from adjacent South African Bantu tribes than between those of Peking and Heidelberg Man.

Clearly too, when mandibles vary so greatly in form between different living races and within two adjacent Bantu tribes, the lower parts of the faces with which those mandibles articulated varied correspondingly. Human faces exhibit a wide range in variation in South Africa alone; we must be prepared therefore to expect a corresponding varietal range of variation in primitive human (viz., australopithecine) faces both in South Africa and elsewhere.

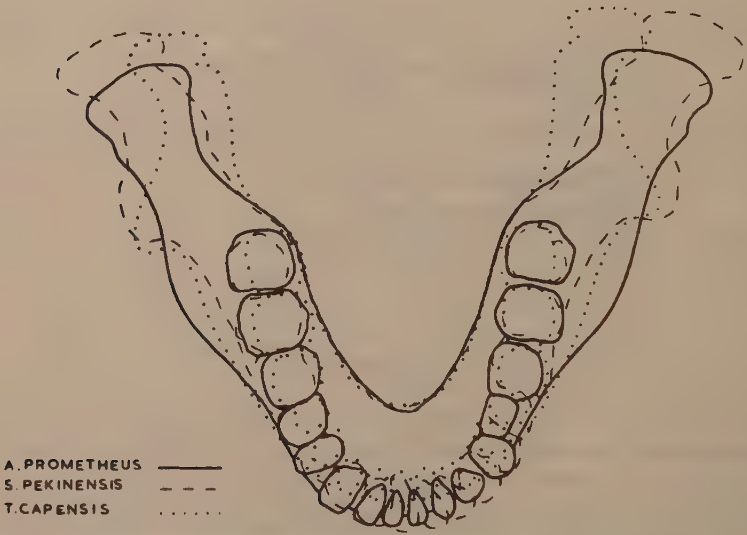

Fig. 7 Superimposition on the occlusal plane of the contours of the adult female *Australopithecus prometheus* mandible (continuous line) upon those of the adult male *Sinanthropus pekinensis* (interrupted line) and *Telanthropus capensis* (dotted line) to show how closely they resemble one another.

The 7th text figure (see fig. 7) portrays a superimposition on the occlusal plane of the contours of the adult female *Australopithecus prometheus* mandible (continuous line) upon those of the adult male *Sinanthropus* (interrupted line) and *Telanthropus* (dotted line, from fig. 57, Broom and Robinson, '52) using the posterior margin of the third molar as a common point for superimposition. It will be seen that the dental arcade in *Telanthropus* is somewhat shorter, and that in *Sinanthropus* slightly longer than in *A. prometheus.* The robusticity of the *Telanthropus* mandible is intermediate in type between that of *Sinanthropus* and *A. prometheus.* The condyles and the posterior limbs of the dental arcade in *Telanthropus* may have diverged further than is indicated in Broom and Robinson's reconstruction; but, even as the reconstruction stands, the resemblances between all three mandibles are sufficiently close to make it intelligible how *Telanthropus* (whose teeth are slightly smaller than those of *A. prometheus* and whose robusticity was also less) should have been interpreted as being human rather than australopithecine.

Dependence upon mandibular characters alone, however, as Burkitt ('28) pointed out, cannot be completely relied upon as an index of cranial and especially cerebral characteristics. The New Caledonians, who had Heidelbergian jaws, had just as great a cerebral capacity as their fellow countrymen with less-primitive-looking jaws.

Finally, in order to exhibit the far greater diversity presented by the mandibles of living human beings, included in the single species *Homo sapiens* by most anthropologists several mandibular profile contours have been superimposed in the same manner in our 8th text figure (see fig. 8) upon the profiles of a Bushman female lower jaw (interrupted line). This specimen A. 43 is from no. 51 *keri-keri,* in the series the Bush females from the Southern Kalahari (Dart, '37) and whose skeleton and the plaster cast of whose cadaver are both in the Museum of the Department of Anatomy.

The other profile contours in ascending order of size are from an Akka Pygmy (light continuous line: after Flower, 1889) a Chinese male indentured as a labourer on the Witwatersrand and buried locally in Germiston (dotted line A. 997 vide Dart, '52); a Scotsman (heavy continuous line): also Nordic in type and from the 6th skeleton prepared in the department 30 years ago: A. 106; and a Loyalty Island male of Australian type (dotted interrupted line: after Burkitt, '28).

The patterns presented by these superimposed mandibles of *Homo sapiens* are not necessarily the most extreme variations known, yet they are so divergent that if specific, much less generic or sub-family status, were to be based on variations in height of the ramus, symphysial contour or general form (whether prelacteonic or postlacteonic), we would need several species (or genera, or sub-families) according to personal predilection to accommodate what most anthropologists are still content to include in a single species with a limited number of races. This diagram shows that the range in variation of prelacteonic and postlacteonic mandibular size and form in the different varieties of *Homo sapiens* is relatively far more considerable than that exhibited by the foregoing *Australopithecus prometheus*, *Telanthropus capensis* and *Paranthropus crassidens* series. These types exhibit the extremes of the various known australopithecine types yet their forms ostensibly belong to a more intimately inter-

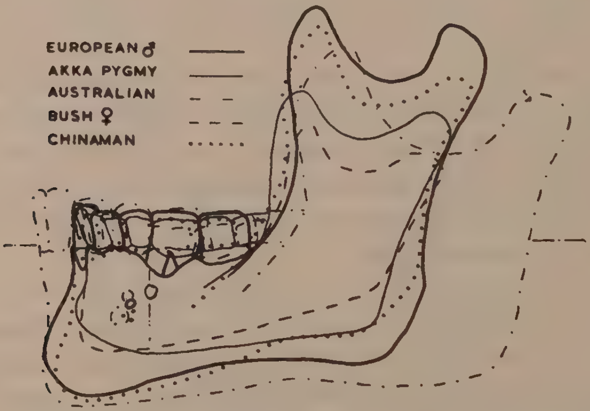

Fig. 8 Profile contours in norma lateralis on the alveolar horizontal and lacteonic coronal planes of sapient human mandibles including the Bush female *keri-keri* A. 43 (interrupted line), an Akka Pygmy (light continuous line: after Flower), a Chinese male A. 997 (dotted line), a Nordic Scotsman A. 106 (heavy continuous line), and a Loyalty Island male of Australian type (dotted interrupted line: after Burkitt, '28) to show the relatively great variation in size and form of their bodies and rami and their prelacteonic and postlacteonic parts.

related series of creatures than in this series of extant human racial types.

RANGES OF MANDIBULAR MEASUREMENT IN EXTANT AND EXTINCT HUMAN TYPES

In the accompanying table are presented the variations in 4 standard comparative profile measurements of extant and extinct human types together with the ranges of variation they exhibit for the living races of mankind and for their predecessors. In the extant human group is included the Bush female *keri-keri* (A. 43) and the Shangaan Bantu mandible with Boskopoid features (A. 1199); as well as Burkitt's Loyalty Islander (cf. fig. 5); in the extinct human group are included the *Sinanthropus* adult female and Heidelberg specimens as well as the 4 australopithecine specimens we have been discussing, so as to make the range of variation in extinct human types as wide as possible.

We have seen that Broom and Robinson's reconstruction of the *Telanthropus* ramus seems rather low; the table corroborates that conclusion because it shows *Telanthropus* with a lower ramus than all of these human mandibles both extinct and recent with the exception of the very small Bush and Pygmy jaws; with which its other measurements, however, are so incongruous.

Whether the *Telanthropus* ramus restoration is correct or not it is apparent that the ranges of variation in the two groups overlap considerably. The *Telanthropus* and *Sinanthropus* female jaws have maximum lengths 3½ cm shorter than that of the Shangaan male. The supra-alveolar heights of the Shangaan, Chinese and Scottish males are greater than that attributed to *Telanthropus* and are equal to or actually greater than those of the *Sinanthropus* female. The Loyalty Islander jaw, like the Mauer jaw it simulates, exceeds in its maximum length in the alveolar lane not only *Telanthropus* and *Sinanthropus* but also *A. prometheus;* and its smallest ramus breadth is greater than in all of these three and even the so-called, but large female *Paranthropus*.

In other words the only australopithecine specimen exceeding all extant human specimens in all 4 of these measurements is the preposterously large and probably dystrophic male *Paranthropus crassidens* specimen. The large *Paranthropus* specimen regarded as female exceeds extant human mandibles in both of these maximum lengths and in its supra-alveolar height, but the maximal length in the alveolar plane is exceeded by that of the Mauer jaw and is only three more than is found in the recent Loyalty Islander jaw. Finally not only the Mauer but also the Loyalty Island mandibles exceeded the female *Sinanthropus,* the female *A. prometheus, Telanthropus* and the large female *Paranthropus* in the width of their rami.

These overlaps in the two ranges of variation between the extant and the extinct human groups are an obvious index of the close proximity of the two groups to one another. What is perhaps even more surprising is the result of comparing the comparative widths of these two overlapping group ranges. In respect of maximal mandibular length *Homo sapiens* has a variational range of 47, while all the extinct human types when expanded to include even the female *Sinanthropus* and the dystrophically large *Paranthropus* have a variational range of only 52.

The supra-alveolar height in the living types of mankind illustrated here has a range of variation of nearly 3 cm, while the extinct types (granting of course the excessively low *Telanthropus* ramus reconstruction) may vary through nearly 4 cm. In regard to maximum length in the alveolar plane and ramus width however, the range of variation in the two groups is virtually identical; actually it is even greater in the living than in the extinct human group.

This wide range of mandibular variation in measurement of the extant human group occurs in what the majority of anthropologists regard as a single human species! These measurements corroborate the deduction made from the study of the variations in living human mandibular form, that the mandible provides no justification for assuming that *Telan-*

thropus is further removed from *Paranthropus* than is the adult female *Australopithecus prometheus. Telanthropus* appears to be rightly regarded as australopithecine and is probably a female *Paranthropus.*

These comparative measurements furnish further implications! They show that, so far as the mandible is concerned, there is no more reason for separating *Sinanthropus* (much less *H. heidelbergensis*) from *Paranthropus* than there is for separating zoologically a Bush (or a Pygmy) woman from a Scotsman (or a Loyalty Islander). Expressed otherwise the mandible furnishes no justification for giving more than racial rank within a single species to all the known extinct types of early mankind including the Australopithecinae. It is doubtful whether their mandibles furnish any justification for separating the extinct from the extant races of mankind.

DENTAL MEASUREMENTS IN AUSTRALOPITHECUS PROMETHEUS AND TELANTHROPUS

Broom and Robinson ('49 and '52) and Robinson ('53) have repeatedly placed emphasis upon the smaller size of the *Telanthropus* molar teeth as a feature differentiating them from those of *Paranthropus.* I pointed out ('48) that the first (14.5 × 14.0) and second (16.5 ×15.0) lower molars of the adolescent *A. prometheus* rivalled in size those of *Plesianthropus* and *Paranthropus* robustus. In *Paranthropus crassidens* the first lower molar varies in length (14. to 16.1) and breadth (13.0 to 15.5) the means being (15.0 × 14.3); the second lower molar varies in length (14.6 to 17.7) and breadth (13.7 to 16.4) the means being (16.0 × 15.0). It is apparent therefore that the adolescent male teeth of *A. prometheus* are large teeth, though not as large as the largest of the *Paranthropus crassidens* teeth.

The first (12.5 × 12.8) and second (14.0 × 14.0) upper molars of the adult female *A. prometheus* can now be compared with those of *Paranthropus crassidens.* The first upper molar of *Paranthropus* varies in length (11.8 to 13.9) and breadth (12.7 to 18.2) the means being (13.0 × 14.9); the second upper molar also varies in length (13.4 to 15.5) and breadth (14.1 to 17.4) the means being (14.4 × 15.9). The form of the adult female *A. prometheus* upper molars is thus more square and the size generally smaller (especially in width) than in *Paranthropus crassidens.*

We now have all three molars of the adult female lower jaw the third lower molar from the left side having been previously (Dart, '48) described as an isolated tooth. Its measurements (14.0 × 14.0) and those of the right one (13.8 × 13.8) can be compared with those of the *Paranthropus crassidens* third lower molar which varies in length (15.4 to 18.6) and breadth (12.9 to 16.7) the means being (17.4 × 14.5).

The first (12.0 × 12.8) and second (14.0 × 14.6) lower molars of the adult female *A. prometheus* are much smaller than the first (14.5 × 14.0) and second (16.5 × 15.) lower molars of the adolescent male *A. prometheus.*

The first (11.9 × 11.9), second (13.6 ×13.1) and third (13.9 × 12.3 and 14.3 × 12.4) *Telanthropus* molars are somewhat smaller even than those of the adult female *A. prometheus,* but the small size of the latter relative to the large size of the adolescent male *A. prometheus* molars shows that the range of sexual variation in the *A. prometheus* group of Australopithecinae, in respect of tooth size and presumably of mandibular size also, must have been considerable. *A. prometheus* is not likely to have had a lesser range of variation in Makapansgat valley than was discovered in the single *Paranthropus* site at Swartkrans in the Sterkfontein valley.

The measurements given here and in Robinson's diagram ('53, fig. 10) demonstrate the very wide range of variation found in admitted *Paranthropus* molars quite apart from those of *Telanthropus.* If our adolescent male and adult female *A. prometheus* are representative average specimens and this promethean australopithecine type only had a range of dental variation, comparable with that already admitted by Robinson (op. cit.) for *Paranthropus crassidens* that range could not avoid including molar teeth as small as or even smaller than those of *Telanthropus.*

The re-examination of the *Telanthropus* dentition has shown (Robinson op. cit.) that the third lower molar is not as was first thought larger but actually smaller than the second molar, especially in the second jaw, whose third lower molar socket could not have accommodated a tooth larger than the second molar. The potential significance of this relative reduction in size of the third lower molar as an advanced human characteristic, however, is reduced firstly by Robinson's own discovery (op. cit.), that the *P. crassidens* mandible SK. 23 on one side showed the same feature; and secondly by the fact that the third lower molar in the adult female *A. prometheus* is also smaller than the second.

The logical conclusion from these dental measurements is either to expand the range of dental variation in *Paranthropus crassidens* to include the two *Telanthropus* dentitions, or to assume that, amongst the *Paranthropus* population, as amongst the Bantu population today two races (respectively macrodont and microdont) are represented in the Swartkrans deposit. In either event it is clear that neither the absolute nor the relative sizes of the *Telanthropus* teeth can be used any more convincingly than those of the adult female *A. prometheus* teeth to prove that a distinct genus of creatures, more human than the Australopithecinae, lived contemporaneously with *Paranthropus* in the Sterkfontein valley of the Transvaal.

SUMMARY

1. The ramus of the adult female *Australopithecus prometheus* had a supra-alveolar height equivalent to that of extant Nordic European males. The reconstructed ramus of *Telanthropus capensis* is as wide as that of *A. prometheus* and probably had the same or an approximately similar height.

2. The height of the body of the *A. prometheus* mandible is intermediate between that of *Telanthropus* and extant Nordic European males.

3. Neither the smallness of the mandible, nor the lowness of the body, nor of its ramus in *Telanthropus* can be relied upon as criteria of generic distinction between *Telanthropus* and other Australopithecinae.

4. The vast range of variation in sagittal sections through australopithecine and living human mandibular symphyses shows that it is reasonable to include the *Telanthropus* symphysis amongst australopithecine variations.

5. There is a greater range of variation between South African Bantu mandibles than there is between those of *A. prometheus* and *Telanthropus* or between those of *Sinanthropus* and *Homo heidelbergensis.*

6. There is as great a divergence between a Zulu female lower jaw and the Mauer, or some New Caledonian and Loyalty Island mandibles as there is between *A. prometheus* and *Paranthropus crassidens* mandibles.

7. Superimposition of the *A. prometheus, Telanthropus* and *Sinanthropus* mandibles reveals their close approximation to one another, but shows that the *A. prometheus*, is nearer to the *Telanthropus,* than it is to the *Sinanthropus* mandible.

8. The range in variation of form in the mandibles of *Homo sapiens* and their individual parts is relatively far greater than it is in the known Australopithecinae! Until disparities greater than those exhibited by living races of mankind are displayed by the mandibles of the *Ausralopithecus* type it is illogical to create from their mandibles divergent races, irrespective of creating different species, genera or sub-families.

9. The known australopithecine and, if Robinson's ('53a) contention is confirmed, the known meganthropine remains all probably belong to a single human species.

10. The ranges in variation of 4 mandibular measurements in living and extinct types of mankind show that there is no more reason for separating the mandibles of all the Australopithecinae (including *Paranthropus* and *Telanthropus*) from *Sinanthropus* and *Homo heidelbergensis*, than there is

for separating the mandibles of Bushman (or Pygmies) from those of Scotsmen or New Caledonian and Loyalty Islanders.

11. The similarity between the mandibles of extinct and extant human beings (e. g. *A. prometheus* or *Telanthropus* and Europeans; or Mauer and New Caledonians or Loyalty Islanders) and the diversity between the mandibles of extant human beings (e.g. Bush and European and New Caledonian or Loyalty Islander) indicate the impracticability of separating extinct from extant human beings in terms of mandibular structure.

12. The dentitions of the adolescent male and adult female *Australopithecus prometheus* demonstrate that the teeth of *Telanthropus* cannot be utilized any more effectively than the lower jaw for the purpose of demonstrating that *Telanthropus* or *Paranthropus* belongs to any genus other than does *Australopithecus*.

In conclusion I wish to acknowledge the assistance given to me by Mr. J. T. Robinson by the loan of the Telanthropus specimens; by Messrs. Alun R. Hughes and N. F. Harington in preparing the illustrations and by Mrs. B. E. Wilson and Miss H. Le Roux in grappling with my manuscript.

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THE POSITION OF THE OCCIPITAL CONDYLES AND OF THE FACE RELATIVE TO THE SKULL BASE IN PRIMATES

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THREE FIGURES

INTRODUCTION

Scientific interest in the position of the joint between head and spinal column and in the position of the face relative to the brain-part of the head dates back far into pre-Darwinian years, largely on account of the early realization that man seems to be nearly unique in these respects among adult mammals. One of the first comparative studies on the relative position of the foramen magnum and the occipital condyles in primates appeared in that little-known, but for its time remarkably advanced "Knochenlehre der Affen" by Josephi in 1787; and the metric investigation of the protrusion of the face in primates was started by Peter Camper in 1782. The first systematic study of the position of the foramen magnum in primates, based on extensive material and considering also age changes, was contributed by Bolk in 1915. Racial and sexual differences in man regarding the position of the foramen magnum and of the occipital condyles had been studied by the writer ('18) as part of his dissertation. In later years the author dealt again with the problem of the relative position of the cranio-vertebral joint with special emphasis on age changes and systematic differences in primates and on the relation of this position to the varying conditions of head balance (Schultz, '42, '49, '50). Of other recent publications appertaining to the position of the occipital condyles in primates are here specially mentioned those by Senyürek ('38) and by Ashton and Zuckerman ('51, '52). The main reason for the long-continued and wide-spread interest in this particular problem is undoubtedly the assumption that an atlanto-occipital joint, located far orally, nearly beneath the center of gravity of the head, is connected with and, if found in fossils, indicative for erect posture. However, the frequent claim that with man's acquisition of the erect posture his head, with its heavy brain, *had* to become balanced on top of the spine, is far from convincing. For instance, in a monograph on the causes and consequences of erect posture in man Knauer ('16) argued that (in free translation): "Such an enormous brain development as man has experienced — the most important result of erect posture — could be reached *only* through the perfected position of equilibrium of the head . . . Alone in this way did weight acquire an entirely subordinate role, since it acts in a position of rest only as pressure on the supporting structure and the muscle apparatus is needed very little to maintain this position." Actually in many monkeys and apes the entire head, with its comparatively large face, forms a greater part of the weight of the body than in man (Schultz, '42).[1] Adult gibbons, e.g., can easily hold themselves erect, yet their very poorly balanced heads are proportionately much heavier than in man (= 7.2 to 7.5 per cent of body weight instead of only 5.4 per cent as in adult man). It may also be pointed out in this connection that in many ungulates, particularly giraffes, camels, lamas and some antelopes, as well as in certain breeds of domestic dogs, the cervical part of the spinal column is held practically erect for most the time, yet their large heads are carried entirely in front of the spine. Bolk ('15) had concluded that upright posture did not *cause* a forward migration of the foramen magnum in man, but rather prevented its migrating backward during growth, as in the apes, adding that (in translation): " . . . bipedal walk found in the primitive, fetal, central position of the foramen magnum a lucky condition, sympathetic to its trend." Very similar arguments have been proposed in regard to the backward shift of the human face and its supposed advantage in connection with head balance in upright posture. Today there exists wide-spread agreement regarding these important problems that in adult recent man the atlanto-occipital joint lies farther forward and the face projects less far forward than in any other adult mammal and that these conditions are somehow connected with man's erect posture. It is also quite generally taken for granted that any fossil species which approaches or equals these conditions in modern man *must* have been nearly [2] or entirely upright.

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[1] In an adult orang-utan, received more recently, the fresh head weighs 12.3 per cent of the entire body weight.

In spite of the very considerable literature dealing with particularly the relative position of the atlanto-occipital joint, the accumulated data still seem inadequate for determining the exact degree of man's specialization in these respects and for the understanding of this human peculiarity. The main reason for the scarcity of really comparable data is the nearly total lack of uniformity in the technique employed by the different authors. The relative position of any cranial structure naturally depends entirely on the orientation or horizon and on the points of reference which are chosen. Bolk ('15) had selected as horizon the greatest endocranial length on which the basion was projected. His "Index basalis" necessitated cutting a skull and relied on a horizon which often cannot be very accurately determined and is of quite limited significance. Senyürek ('38) had placed his skulls in "a plane passing through the prosthion and the lowermost points of the two condyles," measuring the position of the condyles in relation to the distance from prosthion to opisthocranion, the latter projected on this horizon. This technique, designed for the study of ‘‘cranial equilibrium,’’ is hardly suited for other problems since its horizon combines points on the face-part and on the brain-part of the skull, which parts can change ontogenetically and phylogenetically quite independently. For the same reason the ear-eye horizon, employd in determining the position of the occipital condyles by Ashton and Zuckerman (’51, ’52) and by the writer (’42) in one study, is far from ideal, as will be further discussed below. For the investigation of racial and sexual differences in adult man regarding the relative position of the foramen magnum, the writer (’18) had employed the glabella-inion horizon, but for his preliminary reports on the age changes and systematic differences in the relative position of the atlanto-occipital joint among primates, he (’49, ’50) had selected the nasion-basion horizon as best suited for comprehensive comparisons.

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[2] The writer could never understand how any creature can be "nearly upright" in the manner in which Neanderthal man has sometimes been reconstructed with his trunk leaning forward and taking a long step in order to prevent his falling. Such a posture, in which the center of gravity lies well in front of the center of support, is never maintained by any child learning to walk nor by any ape standing on its hind legs. Even in the beginning stages of upright posture the trunk must already have been held *fully* erect, to be most easily balanced, but this bipedal posture changed only gradually from an occasional attempt to a constant habit.

TECHNIQUE AND MATERIAL

The sagittal axis of the cranial base is unquestionably the logical horizon for the study of the location of the face underneath and of the aboral projection of the vault above. On intact skulls this axis can be determined only by its endpoints, the nasion and the basion. The basion is a meaningful and strictly comparable landmark in all mammals at all ages and the nasion, though less ideal, represents the midsagittal point on the anatomical border between the cerebral and visceral parts of the skull and, as such, is not influenced by age or relative size of cranial parts. The ear-eye horizon, on the other hand, depends on points which change in relative position with age and with the general size of the animal, and for these reasons alone should really not be used in comparative investigations. This anthropologically still popular horizon was originally intended only for use in measuring adult man and, as much else introduced by the old and purely descriptive anthropometry (stature, span, etc.), becomes meaningless or at least no longer comparable when applied to the very young and to non-human primates. As shown by many examples in the accompanying figures the position of the porion relative to the skull base can undergo extensive changes with age, and the relative position of the other point for the ear-eye horizon, the infraorbitale, not only changes also during growth, but differs enormously with body size, since small animals always have relatively much larger orbits than have large animals (Schultz, '40). For instance, in the small wildcat *(Felis silvestris)* the orbit is proportionately far larger than in the large lion and a corresponding difference exists between the small Pekingese and the large shepherd dog, illustrated in figure 1. Due to such discrepancies the ear-eye horizon has no really comparable direction in these skulls, nor is it the same thing in a newborn and an adult of one species. In primate skulls, oriented in the ear-eye horizon, the prosthion and the occipital condyles lie more orally than if the same skull is posed in the base horizon, as shown by the sections of the adult *Ateles* in figure 2.

For the present investigation the base horizon, or nasion-basion line, was used exclusively. On this line the following three points were projected: the prosthion (pr), the middle of a line connecting the centers of the occipital condyles, i.e. the condylion (co), and the opisthocranion (op) wherever it is obtained with this orientation of the skull, but without considering any occipital crest. The distances on the base line between these three points and the nasion furnish the three measurements needed for the two indices to be discussed. The first index expresses the distance nasion-condylion in percentage of the distance nasion-opisthocranion and the second index gives the distance nasion-prosthion also in percentage of nasion-opisthocranion, whereby a prosthion lying oral to the nasion is indicated by a plus sign and a prosthion aboral to the nasion by a minus sign. All the data in the tables are based upon these few simple measurements and calculations.

The actual measuring was done on the drawings of the midsagittal sections, made with Martin's diagraph for the

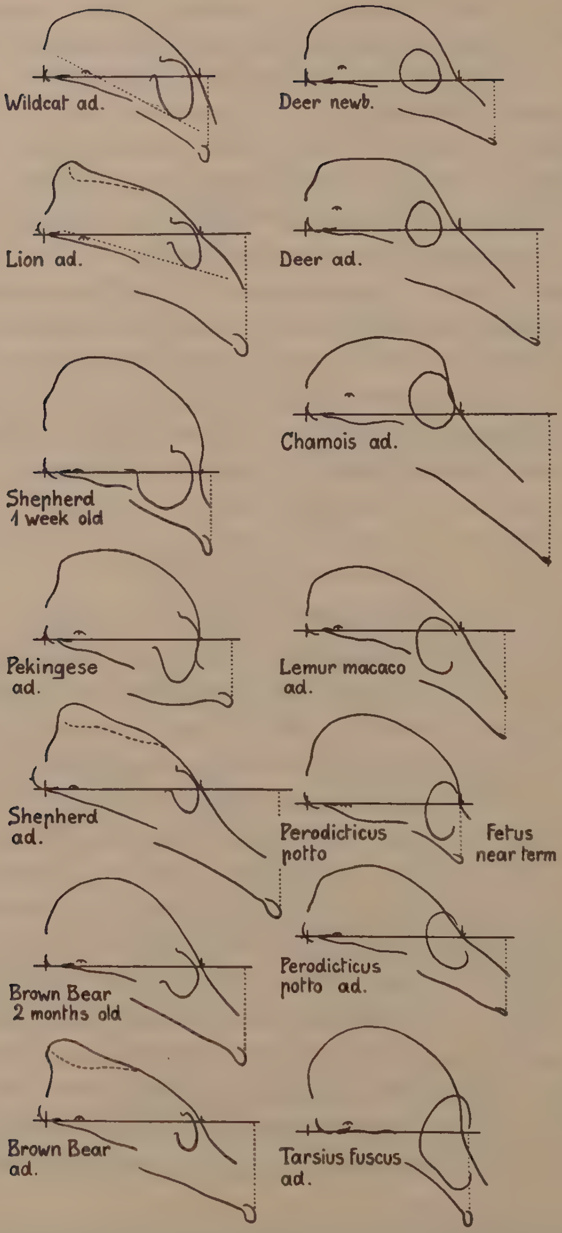

Fig. 1. Cranial midsagittal sections with projected outlines of orbital rims and of positions of condylion and porion of some carnivores (on left), ungulates and prosimians (on right), all reduced to same nasion-opisthocranion length and oriented in nasion-basion horizon. The ear-eye horizon is shown in the first two sections. Sagittal crests are indicated by the broken curves drawn at the base of such crests.

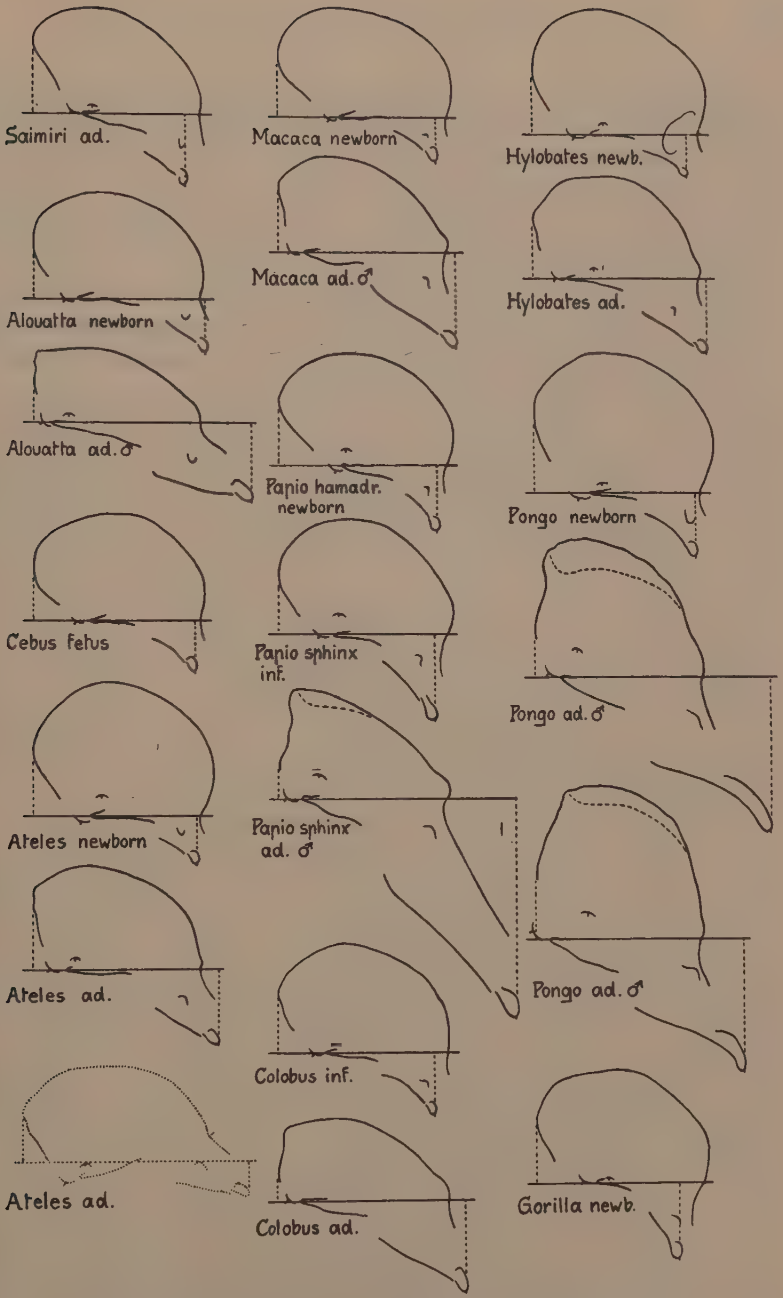

Fig. 2. Cranial midsagittal sections with projected positions of condylion and, in most cases, of porion and infraorbitale of some New World monkeys (left), Old World monkeys (middle) and anthropoids (right), all reduced to same nasion-opisthocranion length and oriented in nasion-basion horizon, except the section in lower left corner wich is posed in the ear-eye horizon for comparison with the same section immdeiately above, posed in the base horizon.

great majority of the medium-sized and larger skulls[3] and made directly on glass applied to midsagittally cut small skulls. Some few of the larger skulls had been cut midsagittally and thus could be drawn directly on glass. All fetal and newborn skulls are from preserved and sagittally cut specimens and were drawn wet. During the later period of this investigation it was found that perfectly accurate results could be obtained with the aid of three-legged dividers with curved legs ending in sharp points. By placing the points carefully at nasion, basion and prosthion, fixing the legs with set screws and transferring them to paper into which three fine holes are pressed with the divider, one obtains the exact relation of the prosthion to the nasion-basion line. The relation between opisthocranion, nasion and basion is then obtained with the dividers in a corresponding manner and marked on the same paper and base line. The position of the condylion, finally, can be plotted by measuring the distance between basion and the middle of a fine needle held with wax across the centers of the two condyles, allowing for the height of the condyles above or below the base horizon. This method, checked repeatedly with the one described before, was used for 34 medium-sized skulls.

The total of the primate skulls thus measured is 470 to which could be added data on the 4 fossil skulls, listed in table 4. The few examples of sections of skulls of carnivores and ungulates, shown for comparison in figure 1, have been selected from the writer's large and varied collection of such diagraphically drawn sections. Nearly all the data for the series of adult human skulls could be obtained from the writer's old drawings made for his dissertation, in which the origin of all this material has already been recorded (Schultz, '18). The few adult and all the young human skulls not used in this former publication are partly from the anthropological institute of the university of Zürich, or mostly from the author's collection. From the latter is also the large majority of the non-human primate material, which could be supplemented by some specimens from the anthropological institute at Zürich and by using some of the writer's diagraphically drawn sections of rarer specimens which he had borrowed formerly from various collections in the U.S.A., chiefly the National Museum. The skulls of 7 of the adult pygmy chimpanzees [4] had been borrowed years ago by Mr. H. J. Coolidge who kindly permitted the writer to measure and draw this rare series. The rare skull of a newborn gorilla has been generously lent by Prof. G. Hirsch, director of the zoological museum in Göttingen. The distribution of the material according to species, age and sex (for adults only) is given in the tables 1 to 4.

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[3] Skulls, too small to be held with the regular clamp supplied with Martin's cube craniophor, were fixed either with the aid of artery clamps attached to Martin's clamp, or else with a lump of plasteline on the shallow bowl which fits the craniophor and is also a standard part of this well-known anthropometric instrumentarium.

THE RELATIVE POSITION OF THE OCCIPITAL CONDYLES

In all the many different mammals, other than primates, which the author could examine, the condylion lies practically as far back as the opisthocranion if the skull is oriented in the nasion-basion horizon. Not infrequently the condyles extend even farther back than any other cranial structure, except an occasional occipital crest (see fig. 1). The condylion index ($\frac{n - co}{n - op} \times 100$), therefore, varies only between about 97 and 106. Even among the infantile and newborn skulls of these mammals the author has found no cases in which the relative position of the condylion is essentially different. It appears, therefore, that there is at least no noteworthy postnatal age change in this respect, comparable to the marked ontogenetic change in monkeys and apes (see figures 2 and 3).

Among the prosimian primates the occipital condyles also lie very near or at the aboral end of the skull, *Tarsius* forming the only exception. In the latter the condylion index averages only about 85, instead of nearly or fully 100, as in the other prosimians. In a fetal potto (see fig. 1) and in a newborn lemur, examined by the writer on midsagittal sections,

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[4] What here has been called simply *Pan paniscus* may really be only a subspecies.

TABLE 1

The indices expressing the relative positions of the condylion and the prosthion in New World monkeys. The figures in parentheses give the ranges of variations in series of at least 5 specimens

SPECIES	AGE	SEX	SPECIMENS	$\frac{n-co}{n-op}$	$\frac{n-pr}{n-op}$
Hapale jacchus	ad.	♀	1	91.2	—8.8
Hapale jacchus	ad.	♂	1	88.9	—6.9
Oedipomidas geoffr.	ad.	♀	1	88.1	—4.8
Oedipomidas geoffr.	ad.	♂	1	87.7	—4.9
Aotus zonalis	ad.	♀	1	91.4	—6.4
Aotus zonalis	ad.	♂	1	89.7	—8.2
Saimiri örstedii	inf.	. .	1	68.1	—6.6
Saimiri örstedii	ad.	♀	5	76.4	—7.4
				(73.7–80.0)	(—8.9 – —6.2)
Saimiri örstedii	ad.	♂	5	78.4	—6.3
				(75.7–80.8)	(—8.5 – —3.9)
Cebus capucinus	fetus	. .	1	72.5	—3.9
Cebus capucinus	inf.	. .	1	74.5	—9.5
Cebus capucinus	ad.	♀	5	85.9	—3.6
				(83.5–89.4)	(—7.6 – 0)
Cebus capucinus	ad.	♂	6	86.6	—1.9
				(83.5–90.0)	(—6.9 – +4.1)
Alouatta palliata	newb.	. .	2	77.1	+3.6
Alouatta palliata	inf.	. .	3	78.7	+0.7
Alouatta palliata	ad.	♀	5	93.8	+24.0
				(93.7–94.0)	(+21.5 – +26.6)
Alouatta palliata	ad.	♂	5	95.1	+32.7
				(93.1–96.2)	(+28.7 – +37.0)
Lagothrix lagothr.	ad.	♀	1	90.9	+7.8
Lagothrix lagothr.	ad.	♂	1	89.0	+9.6
Ateles geoffroyi	newb.	. .	1	72.3	—2.9
Ateles geoffroyi	inf.	. .	3	72.6	—5.3
Ateles geoffroyi	ad.	♀	5	84.0	+6.3
				(78.3–88.6)	(+4.1 – +8.2)
Ateles geoffroyi	ad.	♂	5	84.4	+5.6
				(82.0–85.6)	(+3.8 – +8.2)

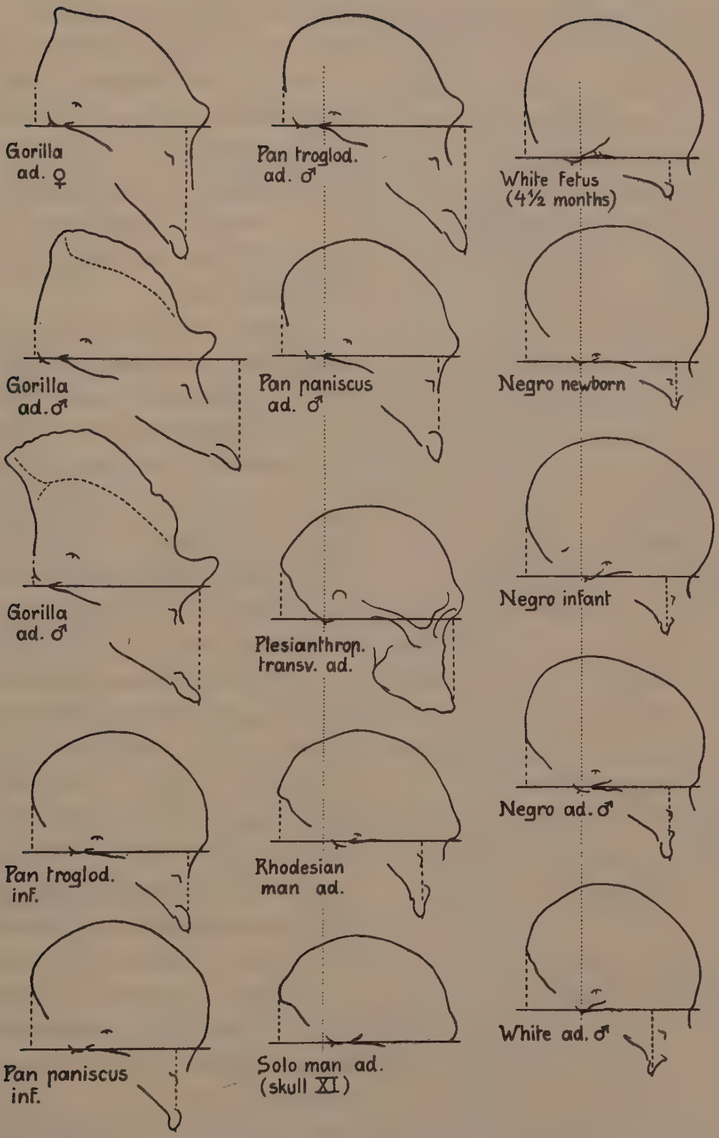

Fig. 3. Cranial midsagittal sections, corresponding to those in figure 2, of some African anthropoids and men. The perpendicular dotted lines indicate in the middle column of sections the position of the condylion in *Plesianthropus* and in the right column of sections the position of the condylion in the newborn and adult White. The section for Plesianthropus ("skull No. 5") cannot claim absolute accuracy, as it was traced from an excellent photograph kindly sent by Prof. Le Gros Clark, the section for Rhodesian man was obtained from a cast and that for Solo man is copied from Weidenreich ('51).

and in another newborn lemur, pictured by Starck ('53), the occipital condyles are situated also very far back on the skull, hardly any differently than in adults. At least these two prosimian types, therefore, are in this respect like carnivores, ungulates, etc. and very unlike all simian primates. From the illustrations of early fetal skulls of *Tupaia, Nycticebus* and *Tarsius,* published by Henckel ('29), it may also be tentatively concluded that the relative position of the occipital condyles undergoes very little change at any time during the ontogeny of these prosimians.

The relative position of the occipital condyles in the suborder of simian primates is shown by the examples in the figures 2 and 3 and expressed by the condylion indices listed in the tables 1 to 4. Among all the adult platyrrhines examined these indices vary individually between 74 and 96, but intraspecifically this range is considerably smaller and differs very significantly in some of the genera. The lowest values are found in *Saimiri* (74–81), a monkey characterized by a markedly protruding occiput even in adults. *Ateles* possesses the second lowest average condylion index and it is noteworthy that individually some spider monkeys have a condylion lying as far orally as in some squirrel monkeys, since the minimum in one of the 5 adult female *Ateles* is 78.3 whereas the maximum among the adult *Saimiri* reaches 80.8. The highest condylion indices are those of adult *Alouatta* in which even the minimum of 93.1 surpasses the values of all other platyrrhines. In every species for which fetal or infantile specimens could be examined the indices are very much lower in the young than in the corresponding adults. This ontogenetic increase amounts to approximately 9 index units in *Saimiri,* 12 units in *Ateles,* 14 units in *Cebus,* and even 17 units in *Alouatta.* In *Saimiri,* therefore, the condyles shift their relative position with growth far less than in *Alouatta.*

In the catarrhine monkeys (table 2) the condylion index varies among adults between 80 and 98, or not quite as much as in the New World monkeys. There are not as pronounced specific or generic differences in this index among the former

TABLE 2

Data, corresponding to those in table 1, for Old World monkeys

SPECIES	AGE	SEX	SPECIMENS	$\frac{\text{n} - \text{co}}{\text{n} - \text{op}}$	$\frac{\text{n} - \text{pr}}{\text{n} - \text{op}}$
Macaca mulatta	newb.	..	3	70.2	−5.6
Macaca mulatta	inf.	..	3	72.0	−11.8
Macaca mulatta	ad.	♀	7	86.1	−0.5
				(80.4–90.4)	(−7.4 – +6.6)
Macaca mulatta	ad.	♂	7	89.4	+4.8
				(86.9–92.7)	(0 – +11.4)
Papio sphinx	inf.	..	3	74.6	−7.0
Papio sphinx	ad.	♀	2	86.7	−5.2
Papio sphinx	ad.	♂	6	95.4	+26.3
				(91.8–98.0)	(+14.2 – +44.9)
Papio hamadryas	newb.	..	1	66.2	−4.6
Papio hamadryas	ad.	♂	2	93.1	+7.0
Papio leucophaeus	ad.	♂	2	91.2	+9.4
Theropithecus obsc.	ad.	♂	1	91.9	+7.1
Cynopithecus niger	ad.	♀	1	86.5	0
Magus maurus	ad.	♂	1	93.8	−2.5
Erythrocebus patas	ad.	♀	1	87.5	0
Cercocebus albig.	ad.	♀	1	93.3	+4.0
Cercocebus albig.	ad.	♂	1	95.0	+6.2
Cercopithecus callitr.	newb.	..	1	62.3	−4.0
Cercopithecus mona	inf.	..	3	75.1	−8.1
Cercopithecus callitr.	ad.	♀	5	88.3	−0.6
				(86.1–90.6)	(−3.0 – +2.6)
Cercopithecus callitr.	ad.	♂	5	90.6	+3.0
				(86.8–94.0)	(−2.7 – +12.4)
Semnopithecus (several species)	ad.	♀	4	91.1	+0.5
Semnopithecus	ad.	♂	4	91.8	+1.2
Colobus (several species)	inf.	..	1	79.3	−7.9
Colobus	ad.	♀	2	88.0	+2.0
Colobus	ad.	♂	3	92.5	+6.8
Nasalis larvatus	fetus	..	1	71.8	0
Nasalis larvatus	inf.	..	2	73.0	−9.2
Nasalis larvatus	ad.	♀	3	85.4	+0.1
Nasalis larvatus	ad.	♂	3	92.1	+2.3
Rhinopithecus rox.	ad.	♀	1	89.9	+2.5

as among the latter. The highest values for adult Old World monkeys are found in the mandrill (maximum of males = 98), but in many other species the index can also reach above 90, particularly in males. As in platyrrhine so also in catarrhine monkeys the indices of the young are very much smaller than those of the corresponding adults. In macaques, e.g., the index rises from 70 at birth to above 86 at the completion of growth, in guenons this postnatal change is even greater, namely from 62 (one specimen only) to above 88, and in the hamadryas baboon an index of 66 in one newborn contrasts with an index of 93 in adults. There is no noteworthy difference between the two subfamilies of catarrhine monkeys in regard to the condylion index and its changes during growth.

Among the anthropoid apes the relative position of the condylion varies in the adult stage, according to table 3, between 77 and 101, the highest value belonging to a male orang-utan and the lowest to a female pygmy chimpanzee. The latter variety of chimpanzee is distinguished by its low average condylion index, though the range of individual variations overlaps that of other chimpanzees quite extensively. In gorillas and orang-utans the average indices for adults are significantly higher than in chimpanzees, and among the Hylobatidae the siamang possesses higher averages than, at least, the white-handed gibbon. Ontogenetically, the condylion index behaves in the anthropoids exactly as in the monkeys, inasmuch as it increases postnatally in all forms to a very marked degree. For instance, in orang-utans the index changes from 71 at birth to 92 and more in adults, in gorillas from 71 in one newborn to above 93 and in ordinary chimpanzees from 66 at birth to about 88 at the completion of growth. In the pygmy chimpanzee, judging by the scant material, the distinctive indices of adults apparently do not appear until late during juvenile life.

It is of interest to note that in a great majority of the monkeys of which at least several adults of each sex could be studied, there exists a marked sexual difference in the condylion index, according to which the females have the lower

TABLE 3

Data, corresponding to those in the preceding tables, for anthropoid apes

SPECIES	AGE	SEX	SPECIMENS	$\frac{\text{n}-\text{co}}{\text{n}-\text{op}}$	$\frac{\text{n}-\text{pr}}{\text{n}-\text{op}}$
Hylobates lar	newb.	..	2	74.6	—6.6
Hylobates lar	inf.	..	3	76.1	—4.5
Hylobates lar	ad.	♀	7	87.2	+7.0
				(84.8–91.9)	(+4.0 – +9.4)
Hylobates lar	ad.	♂	7	91.0	+6.4
				(86.1–97.1)	(+2.8 – +9.4)
Symphalangus synd.	inf.	..	1	80.5	—1.5
Symphalangus synd.	ad.	♀	7	90.8	+12.2
				(87.8–94.0)	(+8.9 – +14.3)
Symphalangus synd.	ad.	♂	7	93.8	+14.2
				(91.7–96.4)	(+9.9 – +17.9)
Pongo pygmaeus	newb.	..	4	71.0	—5.7
Pongo pygmaeus	inf.	..	4	80.6	—3.0
Pongo pygmaeus	ad.	♀	6	91.8	+17.7
				(88.0–96.2)	(+6.4 – +30.5)
Pongo pygmaeus	ad.	♂	10	95.3	+28.2
				(88.5–100.8)	(+15.3 – +40.0)
Gorilla gorilla	newb.	..	1	71.5	—14.0
Gorilla gorilla	inf.	..	7	77.1	—11.1
				(72.0–86.2)	(—17.8 – —5.9)
Gorilla gorilla	ad.	♀	12	93.3	—1.6
				(89.6–97.1)	(—12.9 – +5.3)
Gorilla gorilla	ad.	♂	15	93.9	+11.2
				(86.2–96.4)	(—6.2 – +23.0)
Pan troglodytes	newb.	..	3	66.1	—7.3
Pan troglodytes	inf.	..	7	73.2	—7.7
				(69.2–75.4)	(—11.5 – —6.7)
Pan troglodytes	juv. I	..	7	78.2	—5.7
				(74.9–85.7)	(—13.0 – +1.9)
Pan troglodytes	ad.	♀	15	88.3	+5.9
				(83.0–93.6)	(0 – +13.0)
Pan troglodytes	ad.	♂	17	88.4	+6.7
				(83.6–91.3)	(0 – +12.9)
Pan paniscus	inf.	..	1	74.6	—16.5
Pan paniscus	juv. I	..	1	78.4	—20.6
Pan paniscus	ad.	♀	4	83.6	—2.8
				(76.7–87.9)	(—7.5 – 0)
Pan paniscus	ad.	♂	4	83.2	—1.7
				(82.3–84.3)	(—7.7 – +0.9)

averages and hence are somewhat more infantile in this respect. This same sex difference exists also in gibbons, siamangs and orang-utans, but it is practically lacking in gorillas and chimpanzees as well as in man (see table 4).

As shown by the data in table 4, the condylion index varies individually in adult recent man between 59.6 and 74.4 and, with artificial deformation, the maximum lies even higher. The normal maximum value, found in adult man, surpasses slightly the minimum value in an adult *Saimiri* (73.7) and practically equals this index (74.6) in the fossil adult *Plesianthropus*. The index of the latter differs also very little from the minimum value of 76.7, found in an adult pygmy chimpanzee. It cannot be claimed, therefore, that among all adult primates man possesses the most orally situated occipital condyles. Such a statement is justified only in regard to the *average conditions*. The averages of the condylion index in adult man differ surprisingly little in the racial series which could be studied. The lowest average of 65.8 belongs to the brachycranic series of Alpines, the second lowest (ca. 67) to the dolichocranic series of Australians, and the highest averages, all between 68 and 69, to the otherwise widely different Negroes, Chinese and Eskimos. A sexual difference in this index is, at most, indicated in the Australians, but totally lacking in the other races. That the average condylion index is markedly increased by occipital flattening, as in the Peruvian Indians in table 4, was to be expected. It is of interest to find that in the fossil skulls of Rhodesia and Solo the relative position of the occipital condyles is fully equal to that in recent man.

The ontogenetic changes in the relative position of the occipital condyles of man do not seem to be as uniform and simple as has been commonly assumed. The condylion index averages 68 in the middle of prenatal life, drops to 64 at birth, and to about 61 during infantile growth, to increase thereafter to somewhere near 67 in the adult stage. Incidentally, the infants of Whites and Negroes used here show no consistent difference whatsoever in regard to this index. That

TABLE 4

Data, corresponding to those in the preceding tables, for a few fossils and for recent man

SPECIES OR RACE	AGE	SEX	SPECIMENS	$\frac{\text{n}-\text{co}}{\text{n}-\text{op}}$	$\frac{\text{n}-\text{pr}}{\text{n}-\text{op}}$
Plesianthropus transv.	ad.	?	1	ca. 74.6	ca. +2.2
Rhodesian man	ad.	♂	1	65.1	—17.2
Solo man	ad.	?	2	66.9 and 68.0	. . .
White	fetal	. .	3	68.5	—13.0
White and Negro	newb.	. .	12	64.0 (59.4–68.6)	—8.4 (—10.6 – —5.2)
White and Negro	inf. ca. 8 m.	. .	6	61.4 (60.0–62.2)	—11.6 (—14.0 – —9.9)
White and Negro	inf. ca. 4 y.	. .	6	60.8 (58.8–63.0)	—15.3 (—18.1 – —13.2)
White (Swiss Alpine)	ad.	♀	15	65.8 (61.3–70.4)	—16.8 (—23.3 – —9.2)
White (Swiss Alpine)	ad.	♂	15	65.8 (59.6–71.6)	—17.3 (—22.9 – —10.5)
Australian	ad.	♀	15	66.6 (61.9–70.5)	—11.2 (—16.7 – —6.9)
Australian	ad.	♂	15	67.3 (65.1–70.8)	—11.7 (—16.3 – —6.8)
West African Negro	ad.	♀	15	68.0 (64.4–71.4)	—10.7 (—15.8 – —6.5)
West African Negro	ad.	♂	15	68.3 (64.4–73.0)	—11.8 (—15.3 – —8.3)
Northern Chinese	ad.	♀	10	68.8 (63.3–72.3)	—15.8 (—21.2 – —7.9)
Northern Chinese	ad.	♂	15	68.8 (64.0–72.0)	—18.0 (—25.6 – —12.0)
Greenland Eskimo	ad.	♀	15	68.6 (65.9–74.4)	—14.9 (—20.2 – —11.9)
Greenland Eskimo	ad.	♂	15	68.4 (65.6–70.2)	—16.3 (—20.2 – —13.0)
Peruvian Indian (occip. flattening)	ad.	♂	5	74.6 (70.7–76.7)	—15.3 (—18.0 – —11.6)

the relative position of the atlanto-occipital joint or, to be precise, of the foramen magnum, shifts orally during the fetal development of man is also clearly shown by the beautiful series of photographs of midsagitally cut fetal heads, published by Hochstetter ('43). The later aboral migration of the condyles during juvenile growth, though only slight, follows in its direction the very marked postnatal change typical of apes and monkeys. In the middle of his prenatal life man does not yet differ from many other very young primates regarding the condylion index, since the values for man (67.2–69.8) stand right among the values for such apes and monkeys as the newborn chimpanzees (63.9–69.8), newborn gorilla (71.5), newborn orang-utans (69.5–73.1), newborn Guenon (62.3), newborn baboon (66.2), newborn macaques (69.2–71.6), and infantile squirrel monkey (68.1).

From these findings it can be briefly concluded that only in the suborder of simian primates are the occipital condyles situated far orally in late fetal and infantile stages of their development. This specialized location disappears later in ontogeny in widely varying degrees. In many monkeys and apes the condyles shift backward to the extreme aboral position which exists throughout growth in all other mammals, but in other species, notably *Saimiri*, this ontogenetic aboral migration of the condyles is not as extensive, and in man it is barely indicated. That the specialized fetal position of the condyles, common to simian primates, remains nearly unchanged in man represents undoubtedly a mechanical advantage in erect posture, but it is not necessary for the latter, as shown by individuals with occipital flattening. The condyles have shifted much farther aborally in adult *Symphalangus* than in adult *Saimiri*, yet the former can and does hold itself erect with much greater ease and frequency than the latter. The essential question must still remain unanswered: Why has the joint between head and spine come to lie so far forward early in development in simian primates, if this specialization is not retained by the great majority of species, and is of clear advantage for only one species — man?

THE RELATIVE POSITION OF THE PROSTHION

The prosthion index ($\pm \frac{n - pr}{n - op} \times 100$) serves as an accurate expression of the sagittal protrusion of the face in relation to the skull base. This position of the face has also a direct bearing on head balance since the location of the center of gravity of the head is greatly influenced by the degree of protrusion of the face. As a general rule it is found that in mammals, other than primates, the prosthion lies in front of the nasion, if projected on the base horizon *n–ba,* at the completion of growth. In earlier stages of ontogeny the prosthion lies much nearer the nasal root than in adults. The prosimian primates, besides *Tarsius,* follow this general mammalian rule (see fig. 1). In tarsiers the face retains throughout life its infantile position relative to the skull base, so that the prosthion rarely projects beyond the nasion to any appreciable degree.

The relative position of the prosthion in the suborder of simian primates is shown by the examples in the figures 2 and 3 and by the data in the last columns of the tables 1 to 4. Among adults the prosthion index varies between — 25.6 in a male Chinese and + 44.9 in a male mandrill. In the adult New World monkeys this index lies below 0 in all Hapalidae, *Aotus* and *Saimiri* as well as in a majority of the specimens of *Cebus,* but all *Ateles* and *Lagothrix* have indices slightly above 0 and in all adult *Alouatta* the values have become extremely high, ranging to + 37. Among adult Old World monkeys indices below 0 are rare compared to those above 0, and the species averages differ less than among platyrrhines with the one exception of *Papio sphinx* which is outstanding on account of its very high indices in males.

In adult anthropoids the prosthion index averages below 0 in pygmy chimpanzees and, surprisingly enough, in female gorillas, but in all others the averages lie above 0, more so in siamangs than in gibbons and by far the most in orang-utans. *Plesianthropus* stands in regard to this index clearly among the non-human primates since the indices for man are without any exception much lower. The latter vary individually among adults between — 25.6 and — 6.5. In a number of the prognathous Negroes and Australians the projected prosthion lies relatively less far behind the nasion (indices of —6.5 to — 6.9) than in some adults of *Pan paniscus* (indices of — 7.7 and — 7.5) and of female gorillas (indices even as low as — 12.9), in at least one macaque (— 7.4) and in many platyrrhines (many indices slightly lower than the maximum values for man and as low as — 8.9). It is *not* correct, therefore, to claim that the face of adult man projects forward less far than in any other primates. Such a statement can apply merely to the orthognathous races and, even there, only to the average conditions, since individually the prosthion index of adult Whites and Chinese can be slightly higher than in some apes and monkeys. As was to be expected, the racial differences in the prosthion index are clearly marked in adult man, the averages for Whites and Chinese being roughly — 17, whereas those for Negroes and Australians approximately — 11. The ranges of individual variations are very considerable in most the human series, but less marked than in orang-utans, gorillas and male mandrills which are surprisingly variable in this character (see also examples in the figures 2 and 3).

According to the averages for the human series, the prosthion lies slightly farther aborally in males than in females, an unexpected sex difference which is probably not very reliable in view of the high variability. In the great majority of the monkeys and apes, just the reversed sex difference exists according to the values of the prosthion indices. This sex difference is strikingly developed in howler monkeys, mandrills, orang-utans, and gorillas, in all of which the face projects *much* farther forward in males than in females.

Ontogenetically, the relative position of the prosthion in its projection on the base horizon undergoes very marked change in some primates and very little change in others. For instance, in *Alouatta* the prosthion index is + 3.6 at birth and even only + 0.7 in infantile life, but increases to + 24 in adult females and even + 33 in adult males. In the mandrill the index changes from — 7 in infants (with as yet no significant sex difference) to + 26 in adult males. In orang-utans the average for 4 newborns (which show no sex difference) of — 5.7 shifts to + 28 in adult males. On the other hand, in *Saimiri* the infantile index of — 6.6 (in a male) has remained practically unchanged in adults with an average of — 6.3 for males, and in *Nasalis* the fetal value of 0 equals the average for adult females of + 0.1. In man, in whom the ontogenetic changes could be studied on more material than in other primates, the index of — 13 in the middle of fetal life, changes to — 8 at birth, then gradually back to — 15 at the approximate age of 4 years (without so far any demonstrable race or sex differences), and finally to about — 11 in adult Negroes and — 17 in adult Whites. Generally speaking, the prosthion migrates orally during growth in primates as in the other mammals, but in a majority of the species this change is at best only moderate. In the relatively few species with extremely protruding faces *(Alouatta, Papio sphinx, Pongo)* the postnatal oral migration of the prosthion is by far the most pronounced, whereas in the species with the least protruding faces in adult life, such as *Saimiri, Cebus* and *Homo* the fetal conditions are retained with very little change. It should be emphasized here, that man is not unique among the primates in regard to the position of his prosthion relative to the skull base at any time during ontogeny. Even the finding that in man the prosthion is situated somewhat more orally at birth than later in infantile life, can be recognized also in some other species, such as the capuchin monkey, the macaque, and the proboscis monkey.

SUMMARY

In a total of 470 skulls of monkeys, apes and men of different ages the measuring points condylion, prosthion and opisthocranion have been projected on a horizon determined by nasion and basion. The relative position of the occipital condyles is expressed by the distance betweeen nasion and the projected condylion in percentage of the skull length from nasion to the projected opisthocranion (= condylion index).

For the relative position of the face, as represented by the prosthion, the distance nasion to projected prosthion is calculated in percentage of the same skull length used also for the first index (= prosthion index). If the projection of the prosthion coincides with the nasion, the index equals 0; if the former lies aboral of the latter, the index is negative; and if the reversed relation exists, the index is positive.

In mammals other than primates and in prosimians the occipital condyles are situated practically at the aboral end of the skull, so that the condylion index varies but little around 100, except in tarsiers with an index of ca. 85. This extreme aboral position of the cranio-vertebral joint already exists in these animals, as far as could be determined, at birth and probably even before. In contrast to this, the occipital condyles lie relatively far orally in older fetuses and young infants of monkeys, apes and men, indices between 60 and 70 occurring among the very young of all types of these primates. With growth the condyles shift aborally in widely varying degrees, most extremely so in *Alouatta* among platyrrhines, in *Papio sphinx* and, nearly as much, in some other species among lower catarrhines and in orang-utans, gorillas and siamangs among the highest primates. The average condylion indices in these species reach in the adult to above 90. In *Saimiri,* the pygmy chimpanzee and, particularly, man the relative position of the condyles changes ontogenetically little and among adults man is distinguished by having retained the lowest *average* condylion index. However, the highest and perfectly normal individual value in man (74) equals the lowest variation in an adult *Saimiri* and differs very little from the minimum value for an adult *Pan paniscus* (77) or from that for *Plesianthropus* (ca. 75). Low condylion indices, advantageous for erect adult man, represent fetal specializations of *all* simian primates which change ontogenetically in widely differing degrees, among non-human primates least in the quadrupedal squirrel monkeys, whereas very extensively in siamangs and gorillas which can hold themselves erect with comparative ease.

In the great majority of mammals the face protrudes much more orally in adult than in very young specimens. The suborder of simian primates contains a great variety of forms in which the face, or at least the prosthion, remains behind the nasion in its projection on the base horizon throughout growth. Such a lack of a real facial protrusion in the adult is characteristic of many platyrrhines, a few lower catarrhines, pygmy chimpanzees, female gorillas and, most pronounced, of man. In all these types the prosthion indices change comparatively little with growth and remain below 0. The extreme protrusion of the adult face in howler monkeys, male mandrills and orang-utans is hardly recognizable at the time of birth, but results from a very extensive postnatal change shown clearly in the prosthion indices. Man is not unique at any stage of growth in regard to the relative position of the prosthion since the large ranges of variations in his prosthion indices extend to the corresponding ranges in various other primates. *Plesianthropus* lies clearly outside the range of human variations. In adult howler monkeys, mandrills, orang-utans, and gorillas there has developed a striking sex difference in the relative protrusion of the face which is far greater in males than in females. Since these species have also higher condylion indices in males, it can be concluded that the center of gravity of the head shifts with growth much farther away from the fulcrum in males than in females and that consequently the former require an exceptionally strong nuchal musculature for supporting the head on the spine.

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DISTRIBUTION OF BLOOD FACTORS, ABO, MN AND Rh IN A GROUP OF AMERICAN NEGROES

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The work of L. and H. Hirschfeld in ('19) on the peoples of different races living in the Balkan area was undoubtedly motivated by the earlier observation of Landsteiner ('00 and Decastello and Sturli ('02) in the discovery of the four distinct blood groups in the blood of human beings. These observations by the Hirschfelds have served as an impetus for anthropologists, geneticists, and immunologists for a continuation of racial origin studies. In the United States, many workers have contributed to the volume of data on the American Whites, which studies have shown a high incidence of groups O and A. The studies of Snyder (as in Boyd, '39) and Landsteiner, Wiener and Matson ('42) on the pure American Indian have shown an extremely high incidence of group O and lack of group AB. In the American Negro, the studies of Snyder, and Landsteiner and Levine ('30) showed a high incidence of groups O and B.

With the discovery of the Rh Factor in the blood of human beings by Landsteiner and Weiner in 1940 ('40, '41 and as in Neal and Hanig '51) another serological means was added in describing the genetics of populations. Landsteiner, Weiner and Matson ('42) reported their findings of the ABO blood groups and Rh factors in the American Indian. Levine, ('42) and Wiener, Belkins and Sonn ('44) reported their findings on the American Negro as to the ABO blood groups and Rh factors. Neal and Hanig ('51) reported their results on the incidence of sub-types MNS in the American Negro, while in the same year, Miller, Rosenfield and Vogel ('51) reported the incidence of the Rh-Hr factors in the same group. In 1953 Glass and Li ('53) proposed a method of studying the dynamics of population intermixture based on the frequency of the Rh_0 allele.

In the same paper these authors stated that the preliminary reports of Wiener, Belkins and Sonn ('44) and Levine ('45) were inadequate as samples of the American population, first, because of their small size, secondly, both samples were taken from the New York City Negro population, which may differ considerably in its alleles frequency from the Negro population in other parts of the United States, and thirdly that near and close relatives should be included in a random sample, but no more frequently than the fraction they form of the population studied.

The data about to be presented represents the findings of the blood groups, subgroups and types in a group of American Negroes enrolled in courses taught by the Department of Bacteriology, Preventive Medicine and Public Health, Howard University School of Medicine.

MATERIALS AND METHODS

The student body of Howard University School of Medicine is definitely cosmopolitan as to racial origin. However, the majority of the student body is composed of American Negroes. It is from this segment of the student body, the data to be presented was obtained.

These students represent a random sample of the American Negro population, as their place of birth was listed from all states of the United States, with the exception of Arizona, Idaho, Maine, Montana, Nevada, New Hampshire, New Mexico, North and South Dakota, Oregon, Utah, Vermont, Washington and Wyoming. There were siblings in the group studied, but they did not constitute 0.1% of the population observed.

As the procedure for blood typing was a part of our teaching program, the blood samples were collected by finger puncture and the macroscopic and microscopic determination of the blood groups was read immediately for the benefit of the

SERIES	NUMBER	FREQUENCIES OF GROUPS				GENE FREQUENCIES		
		O	A	B	AB	p	q	r
American Negro								
Howard University (series 1)[1]	1188	53.03	27.20	17.25	2.52	.168	.110	.728
Howard University (series 2)[1]	368	53.50	28.80	14.70	3.00	.166	.150	.731
Howard University (series 3)[1]	937	49.30	27.20	20.00	3.50	.174	.130	.702
Baltimore (Rh Lab)[2]	605	47.60	28.30	20.00	4.10	.180	.132	.688
N. Carolina[3]	500	47.00	28.00	20.00	5.00	.181	.134	.685
New York[4]	730	44.20	30.30	21.80	3.70	.198	.142	.665
American Whites								
New York and North Carolina[5]	30,000	45.20	39.50	11.20	4.20	.248	.078	.674

[1] Howard University this paper.
[2] Glass and Li, '53.
[3] Snyder.
[4] Landsteiner and Levine (W:B).
[5] Snyder (W:B).

(Wiener) W — '43
(Boyd) B — '39

TABLE 2

Frequencies of blood groups and subgroups in the American Negro and American Whites

SERIES	NUMBER	FREQUENCIES OF GROUPS						GENE FREQUENCIES			
		O	A_1	A_2	B	A_1B	A_2B	p_1	p_2	q	r
American Negro											
Howard University (3)[1]	937	49.3	20.7	6.5	20.0	2.9	0.6	.128	.046	.136	.702
Miller et al.[2]	200	50.0	15.0	7.0	23.5	2.5	2.0	.094	.048	.150	.708
Wiener[3]	420	46.8	18.0	9.1	21.3	2.4	2.4	.115	.063	.143	.684
American Whites											
Miller et al.[2]	5,000	43.8	30.4	8.6	12.6	3.4	1.2	.188	.061	.089	.662
Wiener[4]	1,077	41.7	29.0	8.9	13.9	5.2	1.4	.181	.065	.100	.646

[1] Howard University this paper.
[2] Miller, '51.
[3] Wiener, '43 and '44.
[4] Wiener, '44.

students. For the determination of subgroups and types, the blood was collected in small vials containing dried oxalate (0.2 ml of stock solution containing 3 per cent ammonium oxalate and two per cent potassium oxalate in distilled water). The subgroups and types were determined later on the same day. These determinations were done by the microscopic method of Diamond and Abelson ('45).

TABLE 3

Frequencies of MN blood types in the American Negro and American Whites

SERIES	NUMBER	FREQUENCIES OF TYPES			GENE FREQUENCIES	
		M	N	MN	m	n
American Negroes						
Howard University (3)[1]	937	39.7	24.3	36.0	.577	.423
Baltimore (Rh Lab)[2]	907	23.45	28.3	48.25	.476	.524
New York (Miller et al.)[3]	580	24.1	26.2	49.7	.490	.510
New York (Wiener)[4]	278	28.4	21.9	49.6	.532	.468
New York (Wiener)[5]	94	28.7	28.7	42.5	.500	.500
New York (Wiener)[5]	138	29.0	28.3	42.8	.504	.496
Michigan[6]	96	29.25	26.0	44.75	.516	.484
American Whites						
New York[4]	6,129	29.16	21.26	49.58	.550	.450

[1] Howard University this paper.
[2] Glass and Li, '53.
[3] Miller, '51.
[4] Wiener, '43.
[5] Wiener, '44.
[6] Neal and Hanig, '51.

RESULTS

For the sake of clarity, the results of this study will be discussed under the headings of Series 1, 2 and 3.

Series 1 and 2: In these two series, only the ABO blood groups were determined. The distribution of the ABO blood groups are shown in table 1. The higher incidence of blood groups O and B in the American Negro, confirms the findings of the previous investigators. However in our series, the incidence of blood group O is slightly higher and the incidence of blood group AB is a little lower than that found by other workers.

TABLE 4

Frequencies of the Rh blood types in the American Negro and American Whites

SERIES	NUMBER	FREQUENCIES OF Rh BLOOD TYPES							
		Rh_0	Rh_1	Rh_2	Rh_{12}	rh	rh′	rh″	rh′ ″
American Negro									
Howard University[1]	937	44.5	24.6	17.3	5.1	7.3	1.2		
Baltimore (Rh Lab)[2]	907	43.8	25.8	15.4	6.3	7.2	1.4		0.1
New York (Levine)[3]	135	45.93	23.7	16.3	4.44	7.41	1.48	0.74	
New York (Miller)[4]	200	46.5	26.5	16.0	5.0	5.5	.05		
New York (Wiener)[5] (a)	95	24.5	30.8	22.3	11.7	9.6	1.1		
New York (Wiener)[5] (b)	138	41.6	21.2	21.9	7.3	7.3	0.7		
American Whites									
New York (Wiener)[5] (a)	263	3.0	53.2	13.3	16.7	13.3		0.4	
New York (Wiener)[5] (b)	359	2.2	51.2	14.8	19.2	11.4	0.8	0.3	
		GENE FREQUENCIES							
		R_0	R^1	R^2	R^{12}	r	r′	r″	
American Negro									
Howard University (3)[1]	937	.449	.142	.111	.006	.270	.021		
Baltimore (Rh Lab)[2]	900	.446	.145	.101	.015	.268	.025		
New York (Levine)[3]	135	.458	.156	.102	.015	.272	.026	.001	
New York (Miller)[4]	200	.488	.149	.103	.014	.236	.010		
New York (Wiener)[5] (a)	95	.274	.212	.167		.309	.170		
New York (Wiener)[5] (b)	138	.429	.129	.142		.270	.130		
American Whites									
New York (Wiener)[5] (a)	263	.038	.430	.140		.366		.004	
New York (Wiener)[5] (b)	359	.032	.429	.162		.338		.004	

[1] Howard University this paper.
[2] Glass and Li, '53.
[3] Levine, '45.
[4] Miller, '51.
[5] Wiener, '44.

Series 3: In this series, the ABO blood groups, subgroups A_1 and A_2, types MN and Rh were determined.

Blood groups and subgroups: The distribution of the ABO blood groups and subgroups A_1, A_2 are shown in table 2. The higher incidence of blood groups O and B are again noted and that within Group A, subgroup A_1, is more common than subgroup A_2. Our findings are slightly higher than those obtained by Glass and Li for A_1, but they confirm the results of all workers in that the incidence of A_2 is lower in the American Negro than in the American Whites.

MN types: The distribution of the MN blood types are shown in table 3. Our findings do not agreed with the entire work of previous workers, but show a higher incidence of type M and lower incidence of type MN. The incidence of type M is in agreement with the works of the previous investigators. The incidence of type N is approximately the same in the American Negro as in the American Whites.

Rh types: The distribution of the Rh types are shown in Table 4. They confirm the findings of previous investigators of the high incidence of type Rh_0 and the absence of types rh″ and rh′″ in the American Negro. The incidence of types Rh_1 and Rh_{12} is again two to three times higher in the American Whites than in the American Negro. The variation in the Rh types are greater than those found in the MN types or A_1, A_2 subgroups. Thus these variations in the incidence of the Rh types may serve as a basis for studying racial origin or possibly racial admixture.

SUMMARY

1. The blood groups of 2495 American Negroes, whose place of birth was listed in 34 states of the United States and the District of Columbia was determined. The distribution of the blood groups were: Group O — 51.94%. Group A — 27.3%. Group B — 17.32% and Group AB — 3.01%. These results confirm the higher incidence of Groups O and B in the American Negro, as noted by earlier investigation.

2. In a group of 937 individuals, the incidence of subgroup A_1 was found to be greater than subgroup A_2. The incidence was A_1 — 20.7%. A_2 — 6.25%. A_1B — 2.9%. A_2B — 0.6%. The incidence of subgroup A_2 in the American Negro is approximately the same as that found in the American Whites.

3. In the same group of 937 individuals, there was a higher incidence of type M, approximately the same incidence of type N and a lower incidence of type MN than found in the American Whites. The incidence for the three types was M — 39.7%. N — 24.3%. MN — 36%.

4. In the same group of 937 individuals, the incidence of Rh positive was higher than found in the American Whites. The incidence for this group being 91.5% in contrast to 85% in the American Whites. The variation in the incidence of the different Rh types was quite pronounced between the two races. The incidence of the Rh types in the 937 American Negroes was: Rh_o — 44.5%. Rh_1 — 24.6%. Rh_2 — 17.3%. Rh_{12} — 5.1%. rh 7.3%. rh′ — 1.2%. The incidence of the same Rh types in the American Whites was: Rh_o — 3.0%. Rh_1 — 53.2%. Rh_2 — 13.3%. Rh_{12} — 16.7%. rh — 13.3%. rh″ — 0.4%.

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THE INCIDENCE AND FAMILIAL NATURE OF A BONY BRIDGE ON THE FIRST CERVICAL VERTEBRA

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THREE FIGURES

INTRODUCTION

The posterior arch of the first cervical vertebra presents a well-rounded edge on its upper surface for the attachment of the posterior atlanto-occipital ligament. Lateral to this attachment the superior surface of the arch is grooved for the passage of the first cervical nerve and the third part of the vertebral artery and accompanying veins. The groove, the *sulcus arteriae vertebralis,* lies just posterior to the superior articular process on either side.

The sulcus is considered to be the most common condition, but a bony spicule arising from the posterior border of the superior articular process may arch backward over artery, veins and nerve, or even form a complete bony foramen. This spicule, mentioned in the standard anatomical texts (Gray, Morris, Piersol), has been variously described as the ponticulus posterior, the spiculum, or the post-glenoid process in the older osteological literature. Cleland (1861) considered this structure to be a homologue of the superior oblique process, a view shared by Allen (1879) and by MacAlister (1868).

A tendency for bridge (ponticulus) formation has been noted for many years, and preliminary information on its incidence was furnished by MacAlister. However, it remained for Ossenfort ('26) to demonstrate how common this trait really is. Working with dissecting-room material, and museum specimens as well, Ossenfort observed some tendency toward bridging in the majority of specimens.

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Bridging, or process formation may be observed not only in skeletal material, but in the living as well, through the medium of x-rays. Köhler and Zimmer ('53) have called attention to the exostosis-like process on the first cervical vertebra, visible in lateral plates of the cervical spine. Pancoast, Pendergrass and Schaeffer ('42, p. 816) pictured the bony foramen, noting that the spicule might be misinterpreted as a fracture or torn periosteum. Bailey ('52, p. 712) has further called attention to the bridging trait which he considers to be rare in childhood.

Since the bony bridge, or the less complete form can be seen in x-rays, its incidence may be studied in contemporary populations. The x-ray method further affords an opportunity to investigate the development of this trait, during childhood and adolescence. Finally, the possibility also exists of conducting family line studies, with a view toward discovering whether bridge formation is inherited.

It is the purpose of this paper to report on the incidence, development and familial nature of the bony bridge of the first cervical vertebra as seen in lateral-skull x-rays.

METHODS AND MATERIALS

The present study is based on a total of 1414 serial lateral-skull x-rays of 447 men, women and children from Southwestern Ohio. One hundred and six of them were participants in the longitudinal growth studies of the Fels Research Institute, and were 14 years of age or older at the time the most recent skull plate was taken. Two hundred and five of the subjects were parents of participants in the longitudinal studies. The remainder includes siblings of participants, grand-parents or other relatives.

With 7 exceptions, all of whom were Negro, the subjects were white, most of them Ohio-born and generally of "old American" ancestry. The exceptions include a set of monozygotic twins, a set of like-sex triplets, and the parents of the twins. These 7 individuals are included in the family line analyses, and in the twin studies but not in the population frequencies.

The lateral-skull x-rays were taken at a standardized 60 inch tube-to-film distance, being intended originally for cephalometric analyses. In general the first five cervical vertebrae were evident on each plate.

In rating the x-rays, three categories were used; absent bridge, partial bridge, and complete bridge. The category "absent bridge" was assigned when there was no evidence of bridging, or even of a bony spicule projecting over the *sulcus arteriae vertebralis*. The category "partial bridge" was used when there was evidence of spicule formation, calcification in the middle of the bridge, or an incomplete hook-like process projecting posteriorly over the groove (fig. 1). A "bony bridge" was recorded only when a complete bony arch was evident. Examples of absent, partial and complete bridges are shown in figure 1. The slightly more elaborate system used by Ossenfort ('26, p. 440) was not employed here, since the "tubercle" stage could not be readily identified in the x-rays. Otherwise the categories partial and complete bridge correspond to Ossenfort's categories "process' and "complete foramen."

The choice of children 14 years of age and older, for comparison with the adult data, was indicated by a preliminary survey of all of the serial lateral-head x-rays in the Fels files. It was found that with one exception, any tendency toward bridging was manifest by that age. Combining the categories partial and complete bridging, no significant difference was found between these older children and the adults. Children under 14 then, are excluded from the present study, except in describing the developmental aspects of bridge formation.

It should be observed that the longitudinal method of research, with its wealth of serial data, added considerable reliability. When occasional x-rays were unsatisfactory for rating, either because of axial deviations or superimposition

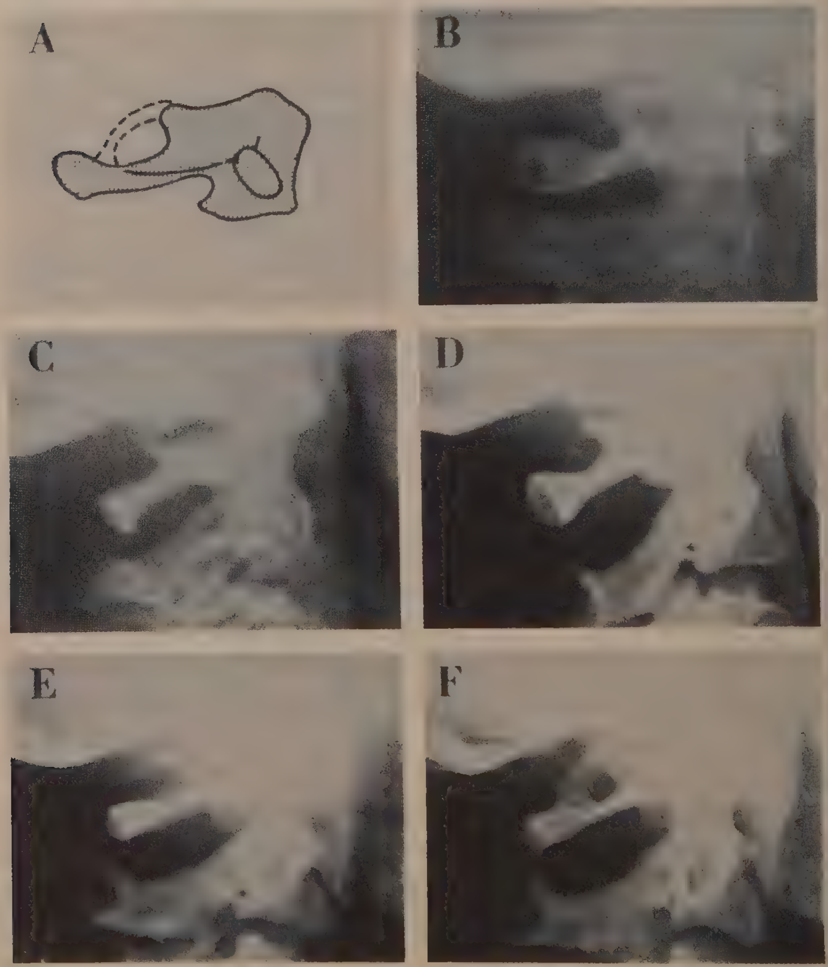

Fig. 1. Variations of the sulcus arteriae vertebralis. A, lateral tracing of a first cervical vertebra showing the sulcus and the location of the bony bridge. B, radiograph showing the usual sulcus. C, partial bridge. D, partial bridge with area of calcification in the center. E, nearly complete bridge. F, complete bilaterally symmetrical bony ring.

of the basal portion of the skull and condyles, reference to the preceding and subsequent x-rays of the same individual usually clarified the situation.

A final word should be added about the group under study. The Fels families represent a fairly wide socio-economic range, though in terms of national origins they are unusually homogeneous. They are not a completely random sample, since 13 sibling pairs are represented among the 205 adults described here. The children moreover, include siblings, and a few cousins as well. However, the adults and the children come from the same genetic pool, and the inclusion of parents and siblings make practicable family-line studies of a kind not ordinarily possible.

TABLE 1

Incidence of bridging in adults and children of both sexes

GROUP	NO.	ABSENT BRIDGE		PARTIAL BRIDGE		COMPLETE BRIDGE	
		no.	%	*no.*	%	*no.*	%
1. Adult males	80	54	67.5	11	13.7	15	18.8
2. Adult females	125	96	76.8	16	12.8	13	10.4
3. Adults	205	150	73.2	27	13.2	28	13.6
4. Boys	48	35	72.9	7	14.6	6	12.5
5. Girls	53	38	71.7	12	22.6	3	5.7
6. Children	101	73	72.3	19	18.8	9	8.9
7. All males	128	89	69.5	18	14.1	21	16.4
8. All females	178	134	75.3	28	15.7 [1]	16	9.0 [1]
9. Total group	306	223	72.9	46	15.0	37	12.1

[1] Significant sex difference in proportion with partial and complete bridge.

FINDINGS

As shown in table 1, bridging over of the sulcus on the first cervical vertebra is a fairly common condition in adults and children over 14 alike. In 205 adults 55 (26.8%) showed the trait, with partial and complete bridging equally common. In 101 children over 14, partial bridging was more often encountered, yet 28 (27.7%) exhibited some degree of bridge formation. Since the two values were not significantly different, the adults and children could be combined to obtain the best possible estimate. Bridging (including both partial and complete bridges) was observed in 83 out of 306 white subjects (27.1%) over 14 years of age.

If males and females are contrasted, the incidence of bridging is slightly but not significantly different. In adults, bridging was observed in 32.5% of the men, and 23.2% of the women. In the children, however, 27.1% of the boys and 28.3% of the girls evidenced the bridging trait. In the total group 30.5% of the males, and 24.7% of the females gave evidence of partial or complete bridge formation. However, the only statistically significant difference was in the proportion with partial and complete bridges. Among females, complete bridges definitely were rarer (table 1).

A total of 31 cases of bridging was observed during childhood, including one set of monozygotic triplets and one set of monozygotic Negro twins (fig. 2). In the earliest case partial bridge formation was apparent at 3½ years; in the latest, bridging did not make its appearance until the 16th year. The mean age at appearance was 9.0 years for the group as a whole. Since 15 of the 31 children progressed to complete bridge formation, while 16 remained in the partial bridge category, it was of interest to compare the mean age of appearance in the two subgroups. The mean age was 7.9 years for the 15 children who went on to completion, as against 10.0 years for the 16 who did not. The difference (2.1 years) falls just short of statistical significance at the 5% level. In one individual bridging was not complete until the 24th year, thus indicating that completion may be delayed until after legal majority. The excess of partial bridges, and deficiency of complete bridges in the children, as contrasted with the adults, serve as a further indication that bridging may be completed in later life. But the bridging tendency, if present at all, seems to manifest itself early as shown both in figure 2 and in table 1.

Because the adults in the present study were all parents of Fels children, and a number of siblings over 14 were also available for study, it was possible to investigate the incidence of bridging in parents, siblings and offspring of affected individuals. As shown in table 2, the incidence of bridging in the siblings of affected individuals was notably higher than in the sample as a whole. Fifty-two and three-tenths per cent of siblings exhibited the bridging trait. Much the same picture

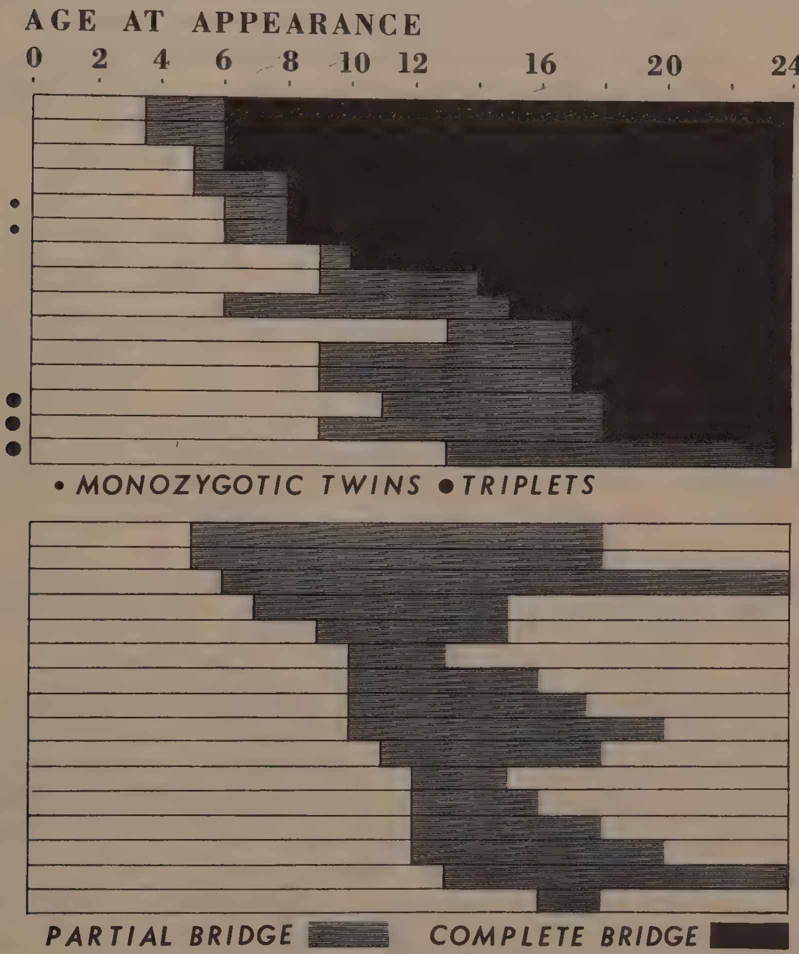

Fig. 2 Developmental records of 31 individuals who achieved partial or complete bridging. The upper group of 15 includes one set of monozygotic triplets and one pair of monozygotic twins. The lower group includes those individuals in whom bridging remained partial.

emerged from the study of the parents. Forty-seven and six-tenths per cent of the parents of affected children evidenced some degree of bridging, again a higher proportion than in the group as a whole.

Since it was evident that relationship to an affected individual increased the chances of having the bridging trait, it was of interest to investigate those cases where only one parent or both parents were so affected. In 18 cases there were children over 14 with one parent affected, and the other definitely lacking bridging in any form. Ten of these 18 children (55.6%) evidenced the bridging trait. Further, there were 8 children over 14 from families in which *both* parents were definitely affected. Seven of these children exhibited bridging. Approximately 50% of the siblings, parents or children of an affected individual, thus exhibited the bridging trait.

TABLE 2

Incidence of bridging in siblings-parents and children of affected individuals

	NO.	ABSENT		PARTIAL		COMPLETE	
		no.	%	*no.*	%	*no.*	%
1. Brothers	25	12	48.0	3	12.0	10	40.0
2. Sisters	19	9	47.4	7	36.8	3	15.8
3. Siblings	44	21	47.7	10	22.7	13	29.5
4. Fathers	18	10	55.6	6	33.3	2	11.1
5. Mothers	24	12	50.0	4	16.7	8	33.3
6. Parents	42	22	52.4	10	23.8	10	23.8

Examination of the pedigrees further demonstrated a tendency for the trait to be handed from generation to generation. In general, if it was present in one generation, it was present in the next. As shown in figure 3, bridging in the parental generation did not always find expression in the children: with a relatively small number of children over 14 this is to be expected. However, there were several cases where bridging was noted in one or more children without definite evidence of bridge formation in the parents.

The presence in the study of monozygotic twin pairs further assisted the analysis. There were 5 pairings, including three for the monozygotic triplets. In all 5 pairings concordance was perfect for the presence or absence of bridging. At the time the pairings were first made, triplet C differed from the others in the extent of bridging — exhibiting a partial bridge while members A and B evidenced complete bridge formation. However, the most recent x-ray placed triplet C in the "complete" category, thus making concordance perfect for the type of bridging as well. (See fig. 2.)

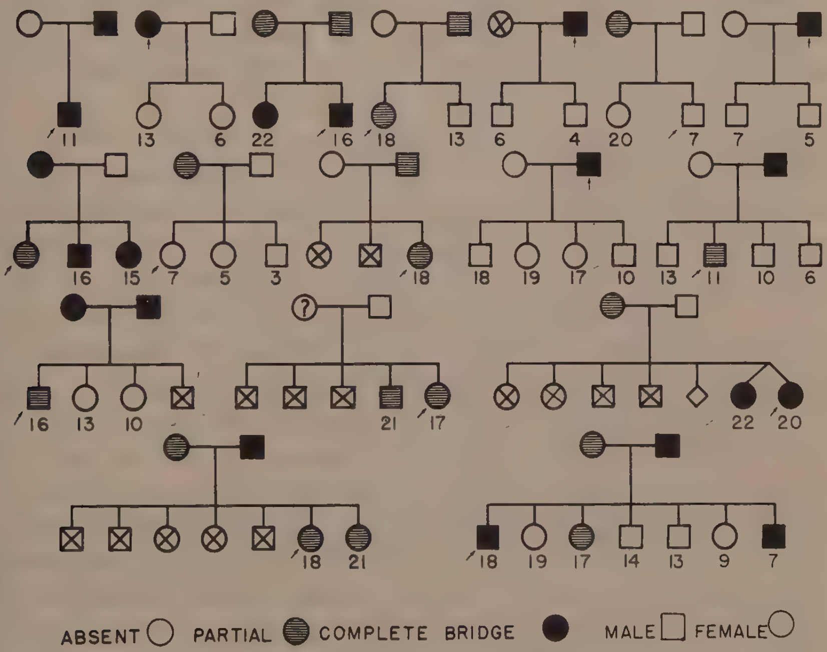

Fig. 3. Seventeen pedigrees showing presence of the bridging trait in one or more generations. Note that bridging in the parents is usually associated with bridging in the children, when the latter are 14 or older. (The ages given above correspond to the most recent skull plate.)

TABLE 3

Incidence of bridging in children of affected parents

GROUP	NO. OF CHILDREN 14 AND OLDER	BRIDGING ABSENT		BRIDGING PRESENT	
		no.	*%*	*no.*	*%*
One parent affected	18	8	44.4	10	55.6
Both parents affected	8	1	12.5	7	87.5

DISCUSSION

In view of these findings it can not be said that the bridging over of the groove for the vertebral artery (on the first cervical vertebra) is either a rare trait, or one limited to ageing individuals. In our material and as shown by x-rays, 27.1% of 306 subjects evidenced some degree of bridging, while complete bridges were observed in 12.1%. Interestingly, the incidence of complete bridging ("complete foramen") was reported as 12% in vertebrae studied by Ossenfort ('26) suggesting that the examination of x-rays and the direct examination of macerated and dried bones may yield comparable results.

Contrary to other reports, bridging does begin early in childhood, as early as the 3rd year, and complete bridging may be noted as early as the 6th. However it does not seem possible to predict, from the age at which bridging first appears, whether and when bridge formation will become complete. In one individual followed in our longitudinal studies, bridging remained incomplete for 19 years. The incidence of complete bridging in the adult material (13.6%) as compared to the children (9%) does suggest that some proportion of individuals noted as having incomplete bridges in late childhood, shift their category during the following years.

While bridging is equally common in males and females alike, there is a sex difference in the proportion with complete and incomplete bridges. In the total group, there was a statistically significant tendency for complete bridging to be more common among males. The bony bridge thus follows the general tendency for bony growths to be more exhuberant in the male, and there is a close parallel with the infraorbital notch (which often becomes a complete foramen in the male). A hormonal explanation, and one relating the bridging tendency to the size and robustness of the first cervical vertebra, are both attractive possibilities, but still premature.

The most interesting findings pertain to the familial nature of this not uncommon trait. Against a "population" frequency of 27.1% the incidence of bridging is markedly higher in close relatives of affected individuals. Fifty two per cent of the siblings of affected children exhibited the bridging trait. Forty eight per cent of the parents of children with bridging evidenced some degree of bridge formation. In contrast only 16% of the parents of unaffected siblings showed any degree of bridging. The data may be summarized by saying that approximately 50% of the siblings, parents or children of affected individuals are also affected. This is compatible with the possibility of Mendelian dominance though other modes of inheritance cannot be ruled out.

Inspection of the pedigrees, moreover, supports this possibility. Though not all of the pedigrees were complete, there was little doubt that the bridging trait appears in successive generations. When it was present in one generation, it was generally present in the preceding or succeeding one. The trait appeared to be ''transmitted'' by either sex. However the sex difference in the proportion of partial and complete bridges, the existence of two phenotypically distinct forms, and the very evident age factor, all indicate that the inheritance is not completely simple; moreover, there are families where bridging appears in the children, but not in the parents.

So far we have not considered the possibility that the ponticulus, or bony bridge as described in this paper is simply the ossified oblique ligament (Hadley, '44, Bailey, '52). While it is not possible to settle this point without anatomical dissections, bridging or process formation is distinguishable from the calcified ligament in x-rays of adults. The post-glenoid process, as described in the older anatomical literature, does not seem to be identical with calcification of the ligament which was observed in only one of the 106 children included in this study.

Our interest in the bony bridge, however, goes beyond the limits of what has been called ''anomaly anatomy.'' This trait is non-pathological. It is neither rare, nor excessively common, and without question it is inherited. Moreover, it can be studied in the living through the medium of x-rays, and in skeletonalized material in the traditional way. The incidence of bridging may therefore be compared in contemporary populations; museum collections may provide information on now extinct peoples. Furthermore, the bony bridge may provide an approach to genetical paleoanthropology, for it is an inherited trait, yet one that persists long after death.

SUMMARY

1. The age incidence and familial nature of a bony bridge on the first cervical vertebra was investigated in lateral-head x-rays of 447 adults and children.
2. Twenty-six and eight-tenths per cent of 205 white adults, and 27.7% of 101 white children over 14 years of age exhibited some degree of bridging. The age difference was not significant.
3. A sex difference was evident in the tendency for males to show a higher proportion of complete bridges.
4. Beginning bridging was observed as early as the 3rd year and as late as the 16th with a mean age of appearance of 9.0 years.
5. Siblings of affected children, and parents of affected children, showed a higher proportion of bridging than in the general population, while the converse was true of the parents of unaffected children.
6. About half of the children of affected parents showed a tendency toward bridging; with both parents affected, the proportion of affected children was nearer 100%.
7. Twin concordance with respect to this trait was high but was not perfect in regard to the extent of bridging.
8. Statistical analyses, and examination of pedigrees, suggest that the trait is familial, genetic, and though influenced by sex, probably inherited as a Mendelian dominant.
9. The possibility of using the bridging trait in the study of past populations was discussed.

ACKNOWLEDGMENTS

The authors express their indebtedness to Doctors Fred Silverman, Mildred Trotter, and Arthur Lewis for assistance in various parts of this study. The aid of Ruth Bean, and the technical assistance of Richard Young is also acknowledged. Mrs. Lois A. Conklin was a great help in the manuscript preparation.

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A NOTE ON THE OS LUNATOTRIQUETRUM

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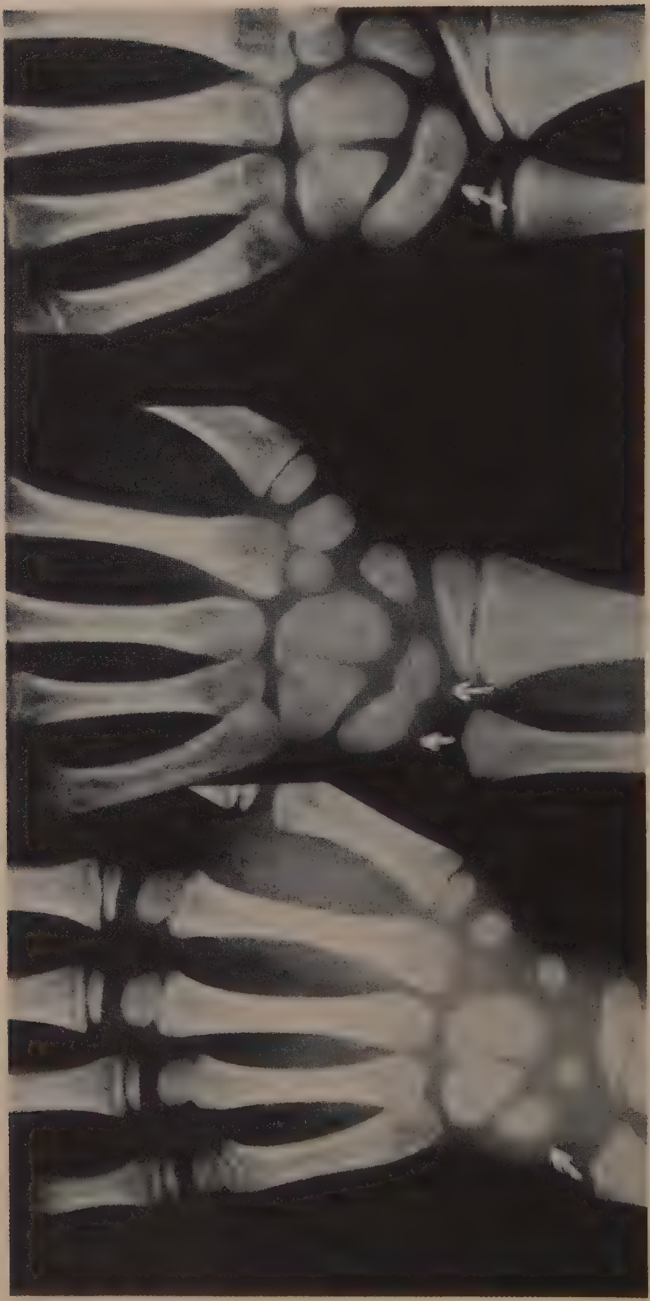
ONE FIGURE

"Fusion" of carpal bones has been recorded on many occasions and "fusion" of the triquetral and lunate bones, the most frequent, is sufficiently common to command recognition as an anatomic entity, the *os lunatotriquetrum,* (O'Rahilly, '53; Dupas & Badelon, '32; Arens, '50; Lönnerblad, '35; Minnaar, '52; Smitham, '48). The incidence of triquetral-lunate fusion is greater in negroid people than white (O'Rahilly, '53; Smitham, '48) and is seen with considerable frequency among certain African groups (Smitham, '48; Minnaar, '52). According to some authors accessory carpal elements are postulated (Pfitzner, Grumbach — cited by O'Rahilly, '53) as playing a role in the development of this and other less common "fusions." Others (O'Rahilly, '53; Smitham, '48) believe that accessory elements are not necessary and that some "fusions" arise as an absence of joint cavitation in the embryo and a transarticular chondrification. None, however, has presented serial roentgen studies of the same patient to support either theory.

Through the courtesy of Dr. John Caffey of New York, the accompanying three films are presented, and appear to support the latter concept. The patient was a negro girl with sickle cell anemia, whose roentgen examination was undertaken because of interest in the skeletal manifestations of this hematologic disorder. A film of the wrist at 6 years of age demonstrated (fig. 1A) the normal number of ossification centers. The several ossification centers were separated from each other



A. 6 years, B. 7 years, C. 8 years.

Fig. 1 Serial X-ray films of wrist in colored female showing sequence of "fusion" of triquetral and lunate bones.

by radiolucent cartilage and carpal anomalies could not be detected. At 7 years of age, (fig. 1B) the ossification centers for the triquetral and the lunate bones approach and appear to overlap each other, as if superimposed by physical factors of projection. When the other ossification centers are studied, it becomes clear that rotation of the wrist is not present, but comparable overlap is seen in other adjacent pairs of ossification centers. At 8 years of age (fig. 1C) the fusion is practically complete, the only vestige of separate ossification centers being a transverse line of increased density at the site of union. A distal groove has not developed, but so long as growth continues, its subsequent radiologic ''appearance'' cannot be precluded. At no place in this series is there evidence of an ossifiied accessory element.

From this series of films and the available literature, it would appear that lunatotriquetral ''fusion'' can represent a genetically determined segmentation error of cartilage, expressed roentgenographically by apparent ''fusion'' of bone without the intermediation of accessory ossicles. The fusion is of ossification centers, not of bones.

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PRECONDYLAR TUBERCLE INCIDENCE RATES

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ONE FIGURE

Some years ago the late Professor Earnest Hooton drew the writers attention to an unusually large pair of precondylar tubercles on the cranium illustrated in figure 1. It was thought worth-while to record the incidence of occurrence of such tubercles on a large series of Oceanic crania, then being studied,[1] for we were unable to locate much data in the literature regarding this phenomenon. Using the original example as ''large,'' a subjective three-point scale evaluation of size was determined. Occurrence and size were recorded, along with indication as to whether one or a pair were present, and whether one tubercle was markedly asymetrical. Results are indicated in table 1.

Sometime after securing these data, it was found that the problem had been discussed in detail by Oetteking ('23, '30), who brought together the literature on the subject. Professor Harry Shapiro drew our attention to LeDouble ('03), not cited by Oetteking, who also discusses the phenomenon. Being a general anthropologist rather than an anatomist, the present writer has little to add to Oetteking and LeDouble's detailed, yet inconclusive, discussion of contradicting explanatory theories of ossification of ligaments, ''vertebral theory of the crania,'' fixed anterior margin of the condyle, and the like.

A year after the first series of 560 Polynesian crania was recorded, a test check of an unsexed series of 97 Hawaiian

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[1] Preliminary results were presented in MARSHALL, Donald S., and SNOW, Charles, ''Polynesian Craniology,'' read at the 1954 meetings of The American Association of Physical Anthropologists. To be published in revised form under the title ''An Evaluation of Polynesian Craniology.''

TABLE 1

Incidence of precondylar tubercles

SAMPLE STUDIED	NO TRACE	?	SMALL		MEDIUM		LARGE		MEDIAL FACETED			TOT
			Dual	Single	Dual	Single	Dual	Single	S	M	L	
Polynesian						Male						
N. Z. Maori, Adult	103	6	15	3	3	3	..	2	..	..	2	1
N. Z. Maori, Subadult	1	..	1	..	..	..	..	..	..	..	..	
N. Z. Moahunter	3	1	1	..	..	1	..	..	..	..	..	
Chatham Islands	20	1	2	..	1	..	..	..	..	1	..	
Samoa	1	..	..	..	..	..	..	..	..	..	..	
Tonga	6	..	..	..	1	..	..	..	..	..	..	
Hawaii, Mokapu	14	..	2	..	1	1	..	..	..	..	..	
Hawaii, General	6	..	..	..	..	..	..	..	..	..	..	
Marquesas	7	..	1	..	..	1	1	..	..	..	..	
Mangareva	1	..	..	..	..	..	..	..	..	..	..	
Niue	1	..	..	..	..	..	..	..	..	..	..	
Easter Island	..	..	2	..	..	..	..	..	..	..	..	
Tahiti	14	1	1	..	..	..	..	..	..	..	..	
Cook Islands	6	..	..	..	..	..	..	1	..	..	..	
Miscellaneous	7	..	2	1	..	..	..	..	2	..	..	
	190	9	27	4	6	6	1	3	2	1	2	2
	[75.7%]				[20.7%]							
						Female						
N. Z. Maori, Adult	62	1	8	1	2	2	1	..	..	1	1	
N. Z. Maori, Subadult	22	..	..	1	..	..	..	..	..	..	..	
N. Z. Moahunter	..	..	1	..	..	..	..	..	..	..	..	
Chatham Islands	22	..	1	1	..	..	..	..	..	..	..	
Tonga	1	..	..	..	..	..	..	..	..	..	..	
Hawaii, Mokapu	7	..	..	..	..	1	..	..	..	..	..	
Hawaii, General	3	..	..	..	..	..	..	..	..	..	..	
Marquesas	1	..	..	..	..	..	..	..	..	..	..	
Mangareva	2	..	..	..	..	..	..	..	..	..	..	
Easter Island	1	..	..	..	..	..	..	..	..	..	..	
Tahiti	6	..	1	..	..	..	..	..	..	..	..	
Cook Islands	1	..	..	..	..	..	..	..	..	..	..	
Miscellaneous	10	..	2	..	..	..	..	..	..	..	..	
	138	1	13	3	2	3	1	..	..	1	1	1
	[84.7%]				[14.7%]							
						Indeterminate						
N. Z. Maori, Adult	28	..	2	1	3	1	1	1	..	..	..	
N. Z. Maori, Subadult	11	..	..	..	..	..	..	..	..	..	..	
Chatham Islands	14	..	1	1	..	..	..	..	..	..	..	
Tonga	2	..	..	..	..	..	..	..	..	..	..	
Hawaii, Mokapu	4	..	3	..	..	..	..	..	..	..	..	
Tuamotu	3	..	..	..	..	..	..	..	..	..	..	
Tahiti	4	..	..	..	..	..	..	..	..	..	..	
Miscellaneous	5	..	..	..	..	..	..	..	..	..	..	
	71	..	6	2	3	1	1	1	..	..	..	
	[83.5%]				[16.5%]							
						Unsexed						
Harvard Hawaii General Series	76	8	4	2	3	..	2	2	..	..	..	
	[78.3%]				[13.4%]							
Melanesian						Comparative						
Fiji, Male	8	..	1	..	..	..	..	..	..	..	..	
Fiji, Female	8	..	..	..	..	..	..	..	..	..	..	
Fiji, Indeterminate	4	..	..	..	..	..	..	..	..	..	..	
	20	..	1	..	..	..	..	..	..	..	..	
	[95.2%]				[4.8%]							
Micronesian												
Guam, Male	20	..	3	..	1	..	..	1	..	..	..	
Guam, Female	11	..	..	..	..	..	..	..	..	..	..	
Guam, Indeterminate	..	..	..	1	1	..	..	..	..	..	..	
	31	..	3	1	2	..	..	1	..	..	..	
	[81.6%]				[18.4%]							

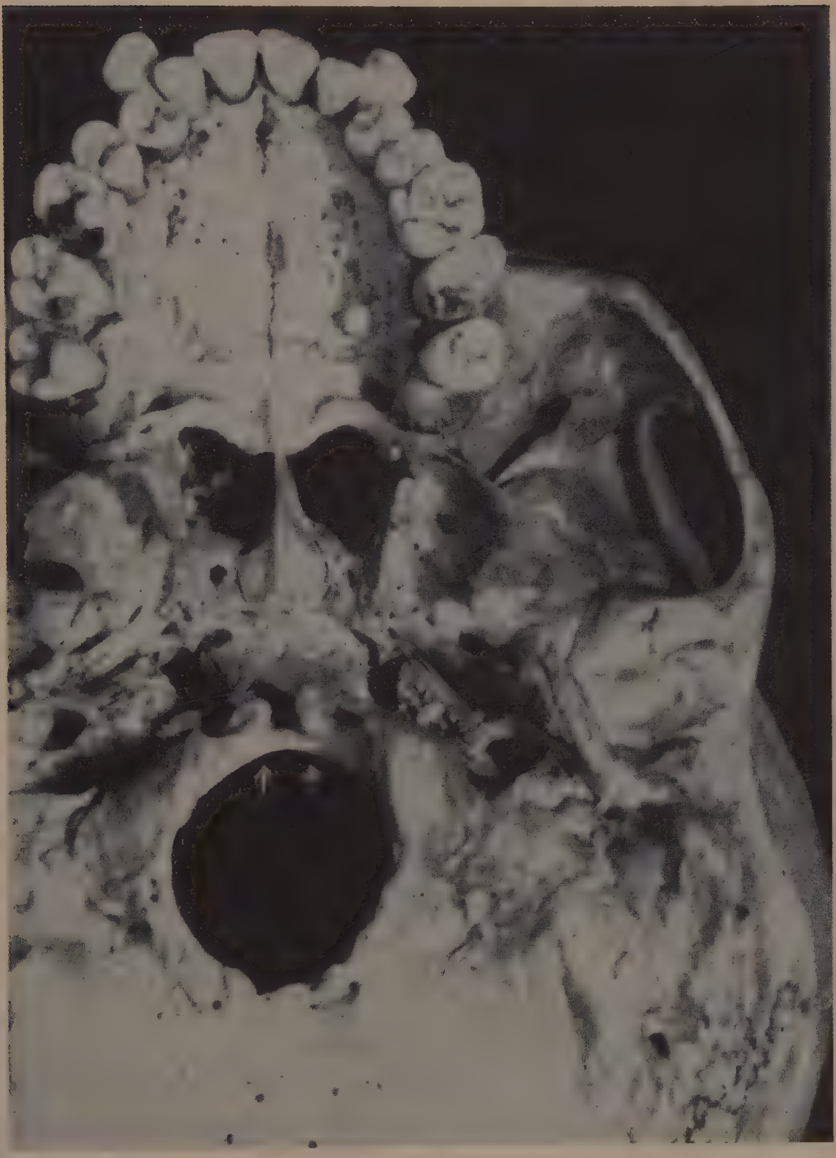

Fig. 1. Ventral aspect of a cranium showing location of the precondylar tubercles.

crania at the Peabody Museum of Harvard was examined for the tubercle phenomenon in order to determine consistency of general rate of appearance, of evaluation and techniques. Results were comparable to those obtained earlier, as well as those given by Oetteking for the Northwest Coast series. The writer finds, as did Oetteking, that the phenomenon is associated with adult crania, with some few exceptions in those specimens which are immediately pre-adult. Tubercles appear on male crania half again as frequently as on female. In many specimens the left tubercle is more robust and lengthy than is the right. There is some subjective indication that artificial deformation practices, present in Polynesia and the Northwest Coast, may accentuate, or in some way be connected with, the size of precondylar tubercles. More obvious, however, in an apparent relationship between the tubercles and general ruggedness of cranial configuration. Polynesian and Micronesian crania show indication of tubercles much more frequently than the small sample of the Melanesian (Fiji) crania which were studied. Polynesian crania are in general less gracile than Melanesian. This variation in degree of robustness may account for the higher rate of incidence in male than female crania in the series.

Making some allowance for judgment as to the presence or absence in the ''question'' or evaluation of the ''small'' category, it is clear that precondylar tubercles appear to some degree in at least fifteen per cent of Polynesian and Micronesian crania. These incidence figures appear related to those given by Oetteking. Of this fifteen per cent, some two thirds are classified as small, one fourth as medium, and one twelfth as large. The ''large'' category would be increased if one included the faceted medium third condyle. The writer believes that the dual tubercles, and in some cases the larger tubercle of an occassional markedly asymmetrical pair, tend to show faceting as the size increases. In the case of larger dual tubercles, there is an indication in some specimens of fusing together to form the medial third condyle. Lacking post cranial remains, it is difficult to discuss functional aspects of faceting, but the dual tubercles and the medial third condyle seem to be related phenomena. Anatomists with whom the problem has been discussed have not been able to offer theories to explain a functional basis for dual tubercles. Correlation analysis of the Polynesian series has yet to be run off, and possible associated phenomena are not as yet readily apparent.

Inasmuch as the examination of large series of crania for evidence of procondylar tubercles may be accomplished in a very brief period, it is hoped that persons with access to such series will add comparative data to that furnished in this note. It would be particularly important to have figures from groups which did not practice artificial deformation, as well as series from negroid and mongoloid stocks. Data cited by LeDouble, presumably for European crania, show considerable variation, and indicate much lower incidence than do those of Oetteking or the writer.

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REVIEWS

THE DISTRIBUTION OF THE HUMAN BLOOD GROUPS. By A. E. Mourant, xxi + 438 pp. $8.75. Blackwell Scientific Publications, Oxford, England, and Charles C Thomas, Springfield, Ill., U.S.A. 1954.

E. W. Count ('50) has stated that the importance of Ripley's *The Races of Europe* and Deniker's *The Races of Man* is only to be understood by realizing that at the close of the 19th century, when these books appeared, anthropologists were in the process of reconciling the already large body of their thought about races with the doctrine of evolution, already accepted for many years by the zoologists. According to Count, it is not Deniker's solution of the problems he considers, but the new way of facing them which is important. Perhaps as a result Ripley's and Deniker's books constitute permanent landmarks in the history of anthropology.

I believe that in 1955 it might be said that anthropologists are in the process of reconciling a still larger body of thought about races with another new doctrine. I refer of course to Mendelian genetics, published by Mendel in 1866, but not noticed by the scientific world until its rediscovery in 1900. The process is now in full swing, and to read papers in anthropological journals in 1955 one might think the transition happened early in the century, when zoologists and botanists proceeded to accept genetics; but examination of papers and books published only a few years ago reveals that a familiarity with genetics is a late acquisition on the part of all but the youngest physical anthropologists, and that in the '30's and '40's the most amazing ignorance of, and misconceptions about, genetics were quite common.

We know, of course, that the now current acceptance of genetic methods by anthropologists is almost entirely a result of the growing interest in the study of blood groups. But this did not come easily. It is true that there was an early period when blood groups were taken over enthusiastically and welcomed whole-heartedly into the anthropological fold. Some workers seemed to believe that the tool invented by L. and H. Hirszfeld during World War I would solve all problems of race by dint of these magic properties hidden in the blood. A good deal of optimistic speculation was indulged in. Professor E. A. Hooton, in *The Indians of Pecos Pueblo,* attempted to pin down, practically to the century, the time of origin of the genes A and B, and he and other writers spoke with facility of mutations and other concepts derived from the new genetics.

This honeymoon proved to be premature. The reason, probably, is that the very workers who thought they were being modern and genetics-minded in their use of blood groups, did not really understand all of the concepts back of the terminology they were using. Part of the difficulty can be traced to the fact that the only books from which one could at that time learn about genetics were books on experimental laboratory genetics, full of mutations, linkage, and alluring 1:2:1 and 9:3:3:1 ratios. The genetics of natural populations was not treated. From such books the incautious enthusiast could easily come away with, for example, the idea that if a character were recessive, just 25% of the population ought to show it. The science of population genetics, which was just being developed, was not available in popular exposition. The concept of race as a matter of populations rather than an attribute of the individual was as yet decidedly not prevalent.

Anthropologists and medical men alike were disconcerted when it became apparent that classification of mankind on the basis of the ABO blood groups (the only ones known until 1927) could, and often did, cut right across the accepetd lines of race based on the conventional criteria. Their first enthusiasm faded into a puzzled bewilderment, and one eminent anthropologist wrote me about 1935 that he proposed to have nothing further to do with "this complicated and possibly irrelevant matter."

This position was but one swing of the pendulum. Already restoring forces were at work. These were of varied nature. One factor was the discovery of the MN blood groups in 1927. Another was the growth of population genetics and the development of adequate mathematical methods for the genetic study of human populations. Another was the steady accumulation of more and more data on the two major blood group systems which were known. My compilation ('39) of the data up to the middle of 1938 did not merely gather dust on the shelves of certain specialized libraries, as I had feared, but was in considerable demand and apparently became part of the standard reference material of a good many workers. My essay on genetic racial classifications, published in 1940, met a much friendlier reception than I had expected, and has been reprinted several times. The book which grew out of that ('50) had a fairly wide distribution.

Trends such as this usually show an accelerated tempo towards the end, and the present trend is no exception. In 1940 Landsteiner and Wiener published their discovery of the Rh factor, which had indeed already been observed by certain other workers, notably Levine. This discovery was found almost at once to have great clinical importance, and it soon became clear that it would also be of capital value in anthropology. Data began to pour into the journals and year after year new Rh factors and new independent systems were discovered. Much of the progress in Rh and no less than two of the new blood group systems are due to the author of the book I am reviewing here. Suddenly the opposition to genetic methods in anthropology appeared to be gone, having melted away like snow in a spring flood, and the problem was now merely, where could one find descriptions of the new blood groups, and how could one get access to the new data, published, as it is, in all sorts of journals, both well known and obscure, in many countries and languages?

These pleas have now been answered. The first was answered by the book by Race and Sanger ('50), reviewed in these pages some months ago, shortly before its second edition appeared. The second has been answered by the book under consideration. Doctor Mourant has somehow found time, along with his duties as director of the busy Blood Group Reference Laboratory at the Lister Institute, and along with his large output of original work in anthropological blood grouping, to collect all the data on the new blood groups, all the MN data not in my 1939 compilation, and all unpublished data on the ABO blood groups. Needless to say, collecting and organizing these data has been no easy task, and the book has been several years in preparation. Now that it has appeared, it is plain that it will occupy a key position in the anthropological literature, possibly similar to that of the books of Ripley and Deniker. This is the first full-fledged book on anthropology solely from the genetic point of view.

The data are collected into a series of 40 tables, according to the blood group system studied and the degree of completeness of the testing. Thus there are two tables of ABO data, one for data reporting simply the 4 classical groups and one for data distinguishing the subgroups of A and AB. There are 14 tables of Rh data containing over 400 series. (This division of the data into many tables of course increases the difficulty of finding an individual series, but producing a single table would obviously have presented formidable typographical and spatial problems.) Other tables contain the data for Kell, Lutheran, and other new blood groups, and there is a table of frequencies of the sickle-cell trait.

Mourant has done much more than merely collect the data. In all but the rare cases where the original authors had calculated the gene frequencies by the method of maximum likelihood, Mourant has calculated frequencies by the excellent approximate methods developed by him. Most of the data are therefore actually more useful in their present form than in the papers in which they originally appeared.

The general features of the world distribution of the various blood groups are shown in an excellent series of 9 maps, drawn to a large scale and showing considerable detail, especially for the European area.

The book is much more than a series of tables and maps. The tables and maps are preceded by 237 pages of text, in which, in a series of 20 chapters, the author, after an introduction, discusses the ABO blood groups, the Rh blood groups, the MNS blood groups, the Lewis blood groups and the secretion of the ABO antigens, the Lutheran, Kell, Duffy, Kidd, and other systems, other gentical characters, the blood group picture in northern and central Europe, the peoples of the Mediterranean area, Africa south of the Sahara, Asia, Indonesia and Australia, the aborigines of America, migrant and hybrid populations, the blood grouping of bone and tissues, the blood groups of animals, an attempt at a synthesis, the collection, preservation and transport of samples, gene frequency calculations, and some recent discoveries. In a simple and lucid style, Doctor Mourant describes the characters of which he makes use and the general genetic picture of the populations in each of the areas mentioned. In these discussions, and in the maps, the older material contained in my compilation is also made use of.

Finally, there are 97 pages devoted to a bibliography of 1716 items, which is intended to include all existing works on the distribution of the blood groups, other than those quoted directly or indirectly in my 1939 article. Titles and inclusive paging are given, and all references which the author could not check are marked with an asterisk.

There is a topographical index to the bibliography, a zoological index to the bibliography, and a general index to the text. The book is well printed in good legible type, on good paper.

An epochal book such as this moves the reader to take stock of what has been done and gauge what still needs to be done. Doctor Mourant devotes a few pages to this question and points ous some of the gaps in our knowledge. He mentions our need for more knowledge of the blood group antigens of the primates and for more knowledge of primate breeding patterns and population genetics. He points to the obvious need for a continuation of the studies of blood groups in relation to disease in man, which have already been so informative as to the evolutionary forces acting on human populations. He points out the great gap in our knowledge of the geography of all except the ABO groups which results from our complete ignorance of the situation in the Soviet Union. He points out the interesting areas of transition between Caucasoids and Negroids in Africa, which need to be studied. He points out that the great continent of Asia offers tremendous opportunities as yet unexploited.

In addition to these and other points raised by Doctor Mourant, I feel impelled to make certain further suggestions. It is important to extend our knowledge of the subgroups of A and AB in the classical system, and to determine the MN groups for many areas which are still unstudied. In particular it is important to determine the subdivisions of the MN groups made possible by anti-S and anti-s, when these sera can be obtained. It is important to test more populations for Rh, using as many of the often rare sera as can be obtained. In order that these sera should be available, it is important that laboratories in as many parts of the world as possible be on the lookout for new sources, which are usually mothers of erythroblastotic infants, or men and women sensitized by repeated transfusions.

It is not likely that many field workers will have the numerous rare sera required, the necessary centrifuges and other equipment, and the requisite laboratory experience, to do these sometimes tricky determinations themselves. It seems likely that most future progress will be done in the way so much of Doctor Mourant's work has been done, by testing blood which has been sent from the field to a central laboratory where all the required sera are constantly on hand. This will call for teamwork and organization, for which the cooperation of Doctor Mourant and his entire group with all persons interested in these problems has already set a very high and inspiring standard.

Naturally in any book which is as comprehensive as this the data included will not all be of equal value. The present volume does not, unlike my 1939 compilation, attempt to mark the less reliable data in any distinctive fashion. For this there are a number of good reasons, explained in the introduction to the tables. However, the group frequencies to be expected from the calculated gene frequencies are given in each case for comparison with the observed group frequencies, and the reader who is curious about any particular item could readily calculate chi-square for himself. It seems likely that the percentage of unreliable data is less than in my earlier compilation, since blood grouping techniques have steadily improved since that time, but Mourant does not discuss this point.

The book seems unusually free from misprints and errors. One slip, although unimportant, may be mentioned. It doubtless resulted from Doctor Mourant's attempts to have the book thoroughly up to date, which led him to include references to much work published in 1953 and even 1954. Some of these references were inevitably put in hastily. In speaking of the method devised by me of calculating gene frequencies from MNS data, he states that it is less laborious than the maximum likelihood calculation, but that it closely approaches the latter in efficiency. This might suggest to some readers that my method is not a proper maximum likelihood method, but this is not so; it is a maximum likelihood method and therefore has full efficiency. If it were not for the fact that book reviewers are expected to detect some errors, presumably as proof of how closely they read the book, I should not mention so minor a point.

Mourant's book should be of use to at least three classes of readers. First it will be necessary for those who wish to learn the applications of blood grouping to racial anthropology, such as students and the few older physical anthropologists who have not yet examined the question thoroughly. Second, it will be indispensable for all who are themselves doing blood grouping on populations, as an instruction book and a source of data for comparison with new results. Third, it will doubtless serve as a body of data on the basis of which anthropologists of the immediate future will erect more detailed and general hypotheses as to the evolutionary forces which have produced the present human races, and as to the human migrations which have produced the racial mixture which was and is one of those forces.

This book will be indispensable to all physical anthropologists who are not primarily archeologists, and the section on the blood grouping of bone may interest some of the archeologists. Nowhere else can there be found combined such a good discussion of the basis of the blood groups and their anthropological application and compilation of all the recent data. Nowhere else can the student find such a careful consideration of all the forces which act to change or stabilize human gene frequencies, or such authoritative presentation of the potential use of the various blood group systems, now and in the future, in tracing racial affinities. The author suggests that we shall probably soon be able to estimate the rates of change of the various gene frequencies under various conditions, and thus acquire a series of quantitative probes into the past of an entirely novel sort.

Future historians of anthropology will very likely find Doctor Mourant's book to have marked the end of an important period of transition, and the beginning of a new and fruitful period of development and discovery.

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THE DISTRIBUTION OF SUBCUTANEOUS FAT IN CHILDHOOD AND ADOLESCENCE. By Earle L. Reynolds. 189 pp. Child Development Publications, Evanston, Ill. 1952.

In man, *tela subcutanea* is the single largest fat depot. This fact, combined with marked individual differences in the amount (and some differences in the distribution) of adipose tissue, makes it an interesting subject matter for anthropologists concerned with body build. The development of a routine roentgenographic method for the measurement of thickness of skin plus the subcutaneous fat at different points of the body surface, in the wider framework of "soft tissue" studies (cf. H. C. Stuart, P. Hill and C. Shaw, Monogr. Soc. Res. Child Devel. No. 26, 1940), opened a wide new area for research on the structure of the living human body, its interindividual and intergroup differences and intraindividual changes.

The Fels Research Institute's soft-tissue study began in 1938 with the aim of describing developmental changes in body structures, in a way which might be useful in relating body build to physiological functions and biochemical processes. The present monograph is a comprehensive presentation of data accumulated at the Institute over a period of some 12 years. The chief aim is to characterize the thickness of the superficial adipose tissue layer (plus skin), at various levels of the body, as seen in roentgenograms of normal children between the ages of 6.5 and 17.5 years (p. 3). Some 9,000 roentgenograms were taken in 176 children, with additional data obtained at several age levels on 80 infants and 256 adults.

The monograph consists of 4 parts: the introductory materials (review of the literature, methodology), group trends, individual differences, and references (230 items).

The review of the literature is useful, even though it leans fairly heavily (in the treatment of European studies) on second-hand sources. It is unfortunate that reference is missing to W. Kornfeld's paper (Child Develop., *18:* 113–129, 1947), containing bibliography of the author's important investigations on the appraisal of physical development, carried out in Vienna. The name of the Czech anthropologist Matiegka is misspelled in the text and the references, and his 1921 paper is grouped with the American studies. Matiegka's revolutionary idea of partitioning the human body into tissue masses seems to have escaped Reynolds (and so many others) who cites the work simply in connection with early uses of skinfold calipers.

In the section on methodology the procedures for taking the soft-tissue roentgenograms are described, including the 6 sites (calf, trochanter, waist, chest, forearm, deltoid) which were examined systematically. The presence and magnitude of radiographic enlargement, due to the divergence of the rays from a central source, is noted but a correction of the measurements of fat breadths on the roentgenograms was not made. Careful positioning of the child has been stressed.

Part II describes age and sex differences in subcutaneous fat. Data indicate a sharp rise in the thickness of the lateral layer of fat at the level of the greatest calf breadth during early infancy, a marked decrease in early childhood, slow decrease in middle childhood followed by a drop in boys and further gain in the girls, thus markedly accentuating the sex differences. Age trends are examined in reference to the individual sites, which show a similarity of growth patterns, and to the sum of the 6 fat breadths. In view of the skewed distributions, percentile norms rather than norms based on the standard deviation as a unit would be preferable.

As to the relations between fat thickness and other body dimensions, the absence of a significant correlation between height and any of the fat breadths (at the age of 15.5 y.) is particularly interesting. It indicates that, at this age level at least, the absolute breadths — without regard for stature — are satisfactory indicators of fatness. Considering the individual sites, in boys the trochanter fat, in girls the deltoid fat is the most representative (shows the highest intercorrelations). Interestingly enough, for both sexes the calf fat shows the lowest intercorrelations.

Individual differences in the amount and distribution of subcutaneous fat were studied in 19 children, including identical twins, an early-maturing and a late-maturing girl, boys differing in body build judged from photographs, and several cases of obesity and marked weight changes. The author brings out the association of somatotypic dominance with differential tissue growth stressing, at the same time, that body build is optimally characterized by combining external measurements with photographs, on the one hand, and with roentgenographic analysis of the relations between the tissue components, on the other. To this should be added, when called for, the densitometric and hydrometric methods for the study of body composition (see Physiol. Rev., *33:* 245–325, 1953).

While the volume is focussed on subcutaneous fat and provides a mass of valuable data on age trends and sex differences, on the interrelations between fat breadths and other body dimensions, and on a number of special problems (sexual maturation and fat deposition, hereditary factors), it will strengthen the salutary trend toward the anthropologist's concern with the *substance* rather than the form of the body alone. It shows, in particular, the importance of the study of tissue composition in interpreting alterations in gross body weight, in which the adipose fat and muscle tissues may follow a diametrically opposite course, and in the quantitative description of body build.

As a postscript, a note may be useful concerning the dating of this monograph. As a number in Volume XV of the Monographs it bears the date of 1950; as Fels Monograph, 1951; as a publication of the

Society for Research in Child Development, it has a 1952 copyright; in reality it left the printer's office at the beginning of 1953.

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LEGG — CALVÉ — PERTHES SYNDROME AND RELATED OSTEOCHONDROSES OF YOUTH. By Charles Weer Goff, M.D., in association with N. M. Shutkin, M.D., and M. R. Hersey, M.D. pp. xxiii and 332; 123 figs., 15 tables, 2 nomographs, 10 graphs, $10.75. Charles C Thomas, Springfield, Ill. 1954.

This monograph is essentially a clinical report to the orthopaedic profession. Hence, physical anthropologists may query the pertinence of a review in these pages. I believe we should know about this book for several reasons: (1) it is about bones — and anything about bones is of interest to us; (2) it employs anthropometric technics in its analysis of LCPS; (3) it discusses the roles of genetics, growth, and race; (4) it relates our science to certain problems in the medical field; (5) it communicates to the medical profession the "whole child" concept; (6) it is a superb example of a single (not simple) problem tackled from a great number of viewpoints (including the experimental). In short, Goff has put some rare old anthropological wines into a new clinical bottle and produced a stimulating concoction in so doing.

The author, after noting modern tendencies to a high degree of specialization, pleads for "a trend toward generalized systems of scientific laws . . . arising in zones where parallel interests touch." Therefore, the purely clinical analysis of LCPS must be supplemented by genetics, growth and development, nutrition, anthropometry, sociology, biochemistry and experimental research. In substance Goff weaves all these strands into a comprehensive picture of the syndrome. His findings are based on a series from the Newington (Conn.) Home and Hospital for Crippled Children: 86 boys, 17 girls.

Some of the more pertinent findings are worth noting. Right hip was involved 44 times, left 41, both sides 18. Age of onset was from 2.5 to 12.8 years, with incidence peak at 6 years in both sexes. Occurrence was greatest in first-born males, second-born females. There is no apparent relation between frequency of occurrence and socioeconomic milieu. There is no endemic or epidemic factor. Trauma occurred in 65% of all cases, but not more significantly in the more vigorous-playing boys. Endocrine imbalance was not a factor, nor were serum cholesterol or alkaline phosphatase. Dietary deficiencies were not found to exist.

It is stated that ''constitutional pre-determinators are proven factors of causality,'' with the Sheldon somatotypic method employed. For 54 boys the type (to the nearest one-half on a 7-point scale) is 3–5–2½, as compared to Sheldon's mean for 46,000 males of 3½–4–3½; for 13 females the type is 4½–4–3. It is also concluded that ''the influence of heredity, as a determinant of variable potentialities, is an obvious corollary.'' There seems to be a racial difference in incidence. LCPS is rare in Negroids, absent in Polynesians, and occurs with equal frequency in Caucasoids and Mongoloids.

Growth as a factor is important to prognosis. ''The younger the child at the onset of an osteochondrosis the less is growth in general affected, either by the child's genetic matrix or by depressant factors which might be inherent within the disorder.'' In older children there is often a growth depression prior to the onset. Recumbency in treatment adds to ''regional deceleration'' of growth.

In my opinion Goff has done a fine job of communication. There may be those who feel, for example, that his treatment of genetics is overly simplified — but he's not writing to or for geneticists! His job is to write to and for his professional colleagues. I think he's combined knowledge, wisdom, and common sense to a remarkable degree.

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EVOLUTION AS A PROCESS. Edited by Julian Huxley, A. C. Hardy, and E. B. Ford. 367 pp. George Allen and Unwin, London. 1954. (Distributed by Macmillan, $4.25.)

While the 19 essays which compose this volume were in preparation, Dr. Julian Huxley reached the age of 65. The other contributors to the volume wrote a foreword, expressing their appreciation of the great services which Doctor Huxley has rendered biology and the study of evolution. Readers of this volume will want to add their thanks and best wishes to those of the contributors. The *New Systematics* and *Evolution, the Modern Synthesis* did much to clarify the modern view of evolution and to make volumes like the present one possible. In the first chapter Doctor Huxley reviews some of the history of the study of evolution and summarizes all the following chapters. The reader is referred to these first 23 pages of *Evolution* *as a Process* for a much longer review and commentary than can be given here. There are several statements on human evolution, and this review will be concerned only with this small portion of the volume.

In the first essay Doctor Huxley summarizes human evolution and stresses the uniqueness of man and the importance of cultural transmission as a new method of evolution. Culture (made possible by the freeing of the hands, brain, and speech) has made man so dominant that he can eliminate any animal which threatens him, and so man becomes "the sole potential vehicle of further evolutionary progress for life." (p. 12). Through his understanding of evolution man is now realizing the possibilities of guiding his own future. Rensch, starting with the problem of the relation of nervous functions to body size, reaches conclusions very close to those of Huxley. In man's line of descent the increase of cortex, prolongation of youth, and speech, made civilization possible and gives man a unique evolutionary position.

Hardy describes paedomorphosis as a way of escape from evolutionary specialization. His application of the principal to man disregards the implications of the australopithecines. Surely, to attribute the "light color of the skin" (p. 137, quoted from de Beer) to paedomorphosis suggests that Negroes are not human and overlooks the possible role of selection in determining color. As Huxley points out (p. 20), paedomorphosis will not account for the special enlargement of the human cortex or the adaptation of feet and legs. A theory which neither accounts for the human brain or locomotor adaptations, nor fits the fossil record, does not seem to offer much to the understanding of human evolution. The papers by Hardy and de Beer show that paedomorphosis has been very important in the evolution of other groups of animals, but the possible contributions of the theory to the study of human evolution need careful re-evaluation.

In a paper on "Correlation of change in the evolution of higher primates" Zuckerman concludes that (p. 349) . . . "It is every bit as likely that some of the Australopithecines represent the forerunners of the modern gorilla and chimpanzee, as that they were ancestors of some group of protohominids, and far more likely than that, as has been claimed, they were themselves protohominids." Zuckerman concludes that the australopithecines were predominantly ape-like on the basis of comparisons of brain size, jaws and face, posture, balance of the head, sagittal and nuchal crests, mechanism of the mandible, teeth, and pelvic bones. He adds, that the australopithecines "provide no clear indication of the major anatomical changes *one would expect* in the transformation of a non-human Primate into a big-brained bipedal animal possessing articulate speech . . .'' (p. 347 [italics mine]). But if changes in the ilium were among the very first which differentiated ape and man and if, as Zuckerman demonstrates, these are not closely correlated with changes in other parts of the body, then the australopithecines *are what might be expected according to some theories.* Are the fossils wrong, or the expectations?

It should be stressed that this review has only dealt with a fraction of *Evolution as a Process.* Many of the other articles are just as important to anthropology although not directly concerned with man. Especially might be mentioned Fisher's review of the criticisms which have been offered against natural selection, Mayr on geographic isolation, Lack on the evolution of reproductive rates, and Corner's delightful essay on the tropical forest. The articles on color vision (Willmer), allaesthetic characters (Cott), and courtship display (Tinbergen) are of obvious importance in interpreting the coloration and behavior of primates. Thanks again to Dr. Julian Huxley!

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BACK OF HISTORY. By William W. Howells. 384 pp.; illustrated, $5.00. Doubleday & Co., New York. 1954.

THE STORY OF MAN. By Carleton S. Coon. xxii + 437 pp. + xiii; 32 plates, 54 figs.; 10 maps, $6.75. A. A. Knopf, New York. 1954.

More beautifully written non-technical accounts of man's rise from Lower Pleistocene obscurity to world dominance have not heretofore appeared. Although the coverage and the source materials used are almost the same, the two books differ markedly in the way the data are handled. In dealing with primate beginnings, fossil man, and modern races, to which this review is restricted, Howells' account is a perceptive, conservative summary of what we know and don't know. Consequently there is little that can be cogently criticized, although I differ with him on a few matters of opinion. On the other hand, Coon's adventurousness often leads him to broad interpretations more distinguished by their brilliance and logic than their grounding in fact. The result is that his book is more exciting and has greater sweep and continuity than Howells'; but there is more in it to be questioned. Consequently, this review is largely concerned with the areas in human biology where Coon seems vulnerable. In my opinion these are largely in Chapter 6, ''The Power of the Sun,'' covering the rôle of adaptive changes in the formation of human races. While

I agree with Coon on the validity of this approach, I feel he has emphasized the importance of adaptations to geographic variations in heat, light, and ultraviolet radiation to the exclusion of other factors such as nutrition. The rather assertive tone of the chapter is not consonant with Howells' wise statement that "For the time being, the argument that [racial traits] are forthright adaptations is less a scientific proof than an appeal to logic, however strong" (p. 157). My concern is therefore with the incomplete statements, overstatements and misstatements that mar the chapter.

The presentation of Gloger's rule (p. 200) is incomplete since it omits the correlation of yellowish and reddish-brown pigmentation with deserts and the reduction of phaeomelanins in colder climates. The cold climate part of Allen's rule is also not mentioned. In applying the ecological rules to man, Bergmann's and Allen's rules are neglected except for the illustrations on pp. 203–205 contrasting a European and an African pygmy, a south Australian and a Nilotic. The obvious question of why antithetical forms such as pygmies and Nilotics exist side by side in hot climates receives only inferential answer (p. 210), which fails to suggest specifically that small body size may be an adaptation to moist tropical forest heat, while attenuated body build seems to be the same for hot dry savannas and deserts.

Overstatements are seen in the animal illustrations of Bergmann's and Allen's rules (pp. 203–204), which cross generic lines, whereas the rules are surely operative only within single species. Using ear length in jack rabbits as an example of Allen's rule not only extends the known range of *Lepus townsendi*, but may be dubious because among Lagomorphs large pinnae are also an adaptive advantage in open prairie and desert country for detecting predators. That "the ears are a rabbit's radiators" (p. 205) is inconsistent with their physiology and behavior under heat stress.

For misstatements, I offer "Negro skin also has a thick superficial horny layer . . ." (p. 208). Maybe, but if Coon means it is thicker than in other peoples, he is only furthering a widely-held and undocumented belief. If instead he is referring to the thickening of the stratum corneum through ultra-violet radiation, this reactive hyperkeratosis is not confined to Negroes. Indeed, it has only been demonstrated for Whites. Another misstatement is that "in climates where the air temperature exceeds that of the body, survival depends upon the organism's ability to lose heat by radiation, convection and evaporation" (p. 202). Actually, if air and effective radiant temperature are that high, radiation and convection do not serve as avenues of heat loss. In the same connection, on p. 205, there is mention of climates where the normal air temperature is above body level. If ''normal'' means the diurnal average, there is no climate that high.

These criticisms are not devastating ones, nor do they reflect upon the book as a whole. Rather, they suggest that some tightening is advisable in a new field where none of us properly rank as specialists. The profession should be indebted to Howells for a beautifully and tightly constructed book, and to Coon for a stimulating and provocative volume that is mostly dead right, but not always.

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FURTHER CONTRIBUTIONS TO THE SOLUTION OF THE PILTDOWN PROBLEM. By J. S. Weiner; W. E. Le Gros Clark; K. P. Oakley; G. F. Claringbull and M. H. Hey; F. H. Edmunds; S. H. U. Bowie and C. F. Davidson; C. F. M. Fryd; A. D. Baynes-Cope; A. E. A. Werner and R. J. Plesters. (Bulletin of the British Museum [Natural History], Geology, Volume 2, Number 6.) 63 pp., 7 figs., 5 plates. London. 1955.

The painstaking re-examination of all the Piltdown finds, if this term can be used to designate objects which were never lost, is described in detail here. The major result of the investigation is well known (Weiner, Oakley, and Le Gros Clark; same volume, Number 2, 1953), and the purpose of *Further Contributions* is to present the evidence in complete detail. Summaries of the chemical analysis, x-ray crystallography, measurements of radioactivity, and other technical procedures will be of great value to palaeontologists and archaeologists confronted with problems of association. The entire discovery has been relegated to the status of a sorry collection of artificially stained Neolithic or Mesolithic flints; a well-traveled group of mammalian fossils (some probably from North Africa and the Mediterranean islands); part of what might be described as a richly hand carved, mahogany stained orang mandible; fragments of an unusually thick (pathological?) subfossil or fossil human skull, also stained to conform to the prevailing color motif; a whittled elephant bone; and a few other items, including the famous isolated canine tooth, the finding of which so gratifyingly confirmed the earlier British Museum reconstruction. An interesting by-product is the detection of a probable second fraud, this time involving Villafranchian bears at another gravel pit in southern England.

Although unmasking the fraud and explaining the technical means by which it was accomplished is surely putting first things first, Piltdown Man is not yet ready for decent oblivion. From the standpoint of the history of science and also from simple curiosity, a reconstruction of the whole episode in terms of human relationships and motives is needed badly. Professor Weiner's forthcoming book will deal with the ''circumstances and sequence of the finds;'' it should be a valuable and perhaps a final addition to the Piltdown bibliography.

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Announcement

Beginning with this issue, a Book Notes section is added to the Journal. The policy of the A.J.P.A. has always been to only publish critical reviews of new books directly related to physical anthropology. This will continue and we expect to have only a few important reviews per issue; important not by virtue of their being about books we should all know but rather in their being detailed and extended critical analyses of the books and their subject matter.

To supplement this review policy we plan a book note section which will promptly mention and briefly describe books of a more-or-less peripheral interest to our readers. As received, such books will be described in brief signed notes (100–200 words). One purpose in making this present announcement is to appeal for help from our readers in making this new section a success. We ask you to volunteer notes on interesting new books or monographs not likely to receive wide notice; or to inform the book review editor of such publications so he can take appropriate action. In this respect, aid is especially needed in the case of books not published in the United States.

As a beginning this section covers accumulated recent books which we did not feel warranted full reviews. In the future your editor hopes to write only a few of the notes in this section and rely almost entirely on contributed aid.

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BOOK NOTES

CHARLES DARWIN. By Ruth Moore, pp. vii + 206. $2.50. Alfred A. Knopf, New York. 1955.

A lively, well written popular account of Darwin's life which should serve well to introduce the college student to the exciting backgrounds to modern evolutionary theory — and possibly to entice him into reading Darwin's own works.

FPT

CATALOGUE DES HOMMES FOSSILES. Edited by Henri V. Vallois and Hallam L. Movius, Jr., pp. 63–378. Fasc. V, Comptes Rendus de la XIX^e Session du Congrès Géologique International, Alger, 1952.

In the name of the Commission pour l'Homme fossile of the Union paléontologique internationale, the editors and their 32 collaborators have developed a reference tool of extreme importance to human paleontology. The catalog covers the world's fossil remains of the family Hominidae and includes all of Pleistocene and immediately post-Paleistocene antiquity. A consistent outline covers the discoverer, date, the site with its geological, faunal and cultural associations, the human remains listed in detail, the repositories for the original and casts, and bibliography. The catalog is arranged by country, and there is a site index as well. For completeness, detail and authority, the Catalogue des hommes fossiles has no peer in our literature.

Copies of the work can be obtained at the price of 500 francs from: Secrétariat Général, XIX Congrès Géologique International, Faculté des Sciences, Alger, French North Africa.

MARSHALL T. NEWMAN

LEGAL MEDICINE. By R. B. H. Gradwohl, Ed., pp. xii + 1093. C. V. Mosby Co., St. Louis. 1954.

While all of the material of forensic medicine is of some concern to physical anthropologists, particular sections of this voluminous and complete reference are of special interest. T. D. Stewart has contributed a lengthy chapter on the evaluation of evidence from the skeleton in which all the available knowledge is expertly summarized. Some 30 tables, charts and plates are utilized in presenting what must be the most complete statement now available in the literature. Not only does Stewart present the criteria for determinations but an experienced evaluation of the probabilities of certainty that each character contributes. D. B. Scott has written a chapter on dental evidence in identification and criminology which parallels Stewart's discussion in some respects but adds considerable detail useful to anthropologists who may use dental evidence in either archeological or related work. Other chapters of special interest include W. E. Evan's on hair and fibers, Gradwohl's on tests of blood stains and grouping procedures in tests for non-paternity, and S. B. Schatkin's on paternity proceedings and blood tests.

FPT

THE ABORIGINAL RACES OF INDIA. By S. S. Sarkar, pp. v + 151, XI plates. Bookland Ltd., Calcutta, India. 1954.

This book is comprised of two reprinted articles, by Eugen Fischer and Sir Arthur Keith, and 5 articles by the author on related aspects of the physical anthropology of India. The first is an account of the relationships between the aboriginal tribes of India based on comparisons of anthropometric data from the living and from skeletal material. A chapter each on Negrito racial strains in India, the Munda in India, ABO blood group frequencies in India, and finger print pattern frequencies in India completes the volume. An appendix includes a description of the disposal of the dead in Harappa and 10 photographic plates. This book ranges from the "old" to the "new" in problem, method and outlook.

FPT

THE ESKIMO SKELETON. Contributions to the Physical Anthropology of the Aboriginal Greenlanders. By Jørgen Balslev Jørgensen, pp. 158 + 18 plates. I Kommission Hos C. A. Reitzels Forlag, Bianco Lunos Bogtrykkeri. 1953.

This is a detailed comparative study of the Eskimo skeleton in which the published data plus new data derived from measurements of various museum specimens are applied to questions of Eskimo origin and sub-group relationships. Traditional standard measurements of 277 crania and 135 other whole skeletons are presented. The material comes from sites in Greenland, on Hudson Bay and a very few from Alaska. Two physically different groups from Greenland were found, yet high concordance with more western Eskimo groups leads to conclusions of origins in northern Asia rather than from American Indian or Mongol groups. High frequencies of various pathologies are reported. A list of references and 18 high quality photographic plates illustrate the text.

FPT

BADANIA NAD CZESTOSCIA GRUP KRWI. (Studies in the Blood Group Frequencies, Especially of the Population of Poland.) By Andrzej Kelus, Stanislaw Dubiski and Roman Szuszkowski, pp. 53. Polish Anthropological Society, Wroclaw. 1953.

This reports blood group findings for ABO, Secretor, MN, P, Rh, Lewis and Kell-Cellano for samples derived from the general Polish population since the war. Comparative tables of reported frequencies from the literature and for many parts of the world are also given. Unfortunately no post-1930's frequencies, and only ABO are reported from the Soviet Union. The text is in Polish with an English summary and vocabulary for the tables.

FPT

WCZESNOSREDNIOWIECZNE CZASZKI POLSKIE z OSTROWA LEDNICKIEGO. (The Early Mediaeval Polish Skulls of Ostrow Lednicki.) By Franciszek Wokroj, pp. 171. Polish Anthropological Society, Wroclaw. 1953.

Some 1500 skeletons and other artifacts were recovered by 1935 from this site, giving evidence of occupation from the Late Paleolithic through the medieval period. Much of these were destroyed during the last war yet 55 measures and 18 indices on *each* of 671 specimens are given in detail in this report together with statistical analyses of these measurements by age and sex. Anomalies, deformities and pathological involvements are not described here but are planned for a future report. One of many interesting findings is the apparently greater life span of males compared to females (59% reaching *maturus* and 8.4% *senilis* compared to 34% and 5% respectively for females). An English summary and a bibliography are included.

FPT

INDIAN HEALTH IN ARIZONA. By Bertram S. Kraus with the collaboration of Bonnie M. Jones, pp. 164. Bureau of Ethnic Research, University of Arizona. 1954.

Sub-titled "A Study of Health Conditions among Central and Southern Arizona Indians"; this report gives a statement of the modern health status of the Arizona Indians, of cross-cultural factors in health administration for the Indian Service, and a summary of present facilities dealing with health problems of these people. While admittedly designed for Indian public health administrators, the section on growth and physical constitution of Indian children is of particular interest to physical anthropology. Kraus has made comparisons of the Wetzel Grid status of 1291 children from three Indian groups (Apache, Papago and Pima) and White children from Tucson. Clear differences in growth pattern occur between these groups with the Pima showing the greatest proportion of "heavy obese" and "stocky" types and all the Indian groups deviating from Wetzel's central channel more than the White children. Graphs, figures and tabular material together with concise discussions make up the body of the report.

FPT

IMPAIRMENT STUDY — 1951. Pp. 300. Compiled and published by the Society of Actuaries. 1954.

A comprehensive study of the mortality among persons with medical impairments gathered from the records of the larger Canadian and United States insurance companies is reported in this book. The data include exposure to risk, actual deaths, expected deaths, the ratios of actual to expected deaths by broad age and duration groups for each of the impairment classifications. Diseases of the cardiovascular, central nervous, respiratory and genito-urinary systems, as well as female diseases, tumors, metabolic diseases and other miscellaneous impairments are considered by specific entities under these broad headings. Except for spinal curvature, no systematic analysis in terms of skeletal anomalies are given, nor can frequencies of impairment in the total insured population be gotten from this study. A general conclusion that impaired persons are a greater insurance risk than unimpaired, while generally valid, seems to depend in fact on the sort of condition that is involved. The mortality experience and the causes of death by age in the various categories covered are valuable data.

FPT

ANTHROPOMETRY OF FLYING PERSONNEL — 1950. By H. T. E. Hertzberg, G. S. Daniels, and E. Churchill, pp. vi + 134. WADC Technical Report 52–321, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio. 1954.

The authors' abstract describes this monograph as follows: ''Body size data for 132 measurements of over 4,000 Air Force flying personnel are presented. Organization of the survey is briefly discussed and the techniques of measurement are illustrated by photographs for the benefit of other anthropologists. Both diametral and surface measurements are included. Dimensions are given in both centimeters and inches.

''A description of the statistics and an explanation of their use are given with some discussion of certain statistical short-cuts employed in the reduction of the data. The tabulations include range, mean, standard deviation, coefficient of variation, and twenty-five selected values from the first to ninety-ninth percentile. Means and standard deviation values for each dimension are also given for nine subgroups based on flight duties.''

A glossary and bibliography are included in this report which is primarily arranged for use by designers of aircraft clothing and equipment. More importantly, it is a fundamental contribution to the development of functional anthropometry as well as a valuable report of data.

FPT

THE HUMAN MASTICATORY APPARATUS. An Introduction to Dental Anthropology. By Meyer Klatsky and Robert L. Fisher, pp. xxi + 246. Dental Items of Interest Publ. Co., Inc., Brooklyn. 1953.

Klatsky and Fisher have written an extremely interesting series of articles on dental anthropology which first appeared in *Dental Items.* The topical coverage may be best mentioned by listing the chapter headings, as follows: Evolution and Dental Degeneration; Factors Influencing Growth and Development; Dental Anthropology; Diet and Its Effects on the Masticatory Apparatus; Dental Caries: Its Causes, Incidence and Prevention; Periodontal Disease; Malocclusion; Dentistry as a Public Health Service; Biologic Dental Restorations; The Relation of Genetics to Dental Science; Dental Anomalies; The Future of the Third Molar; and General Summary and Conclusions. In a book note we can hardly add much to what is clear from the table of contents except to say that non-human primate material, some original data from the author's research, as well as practically all of the classical materials dealing with dental anthropology are included. This book serves as a general reference, as a source of stimulation for further work and as a statement of where we now stand in dental anthropology.

FPT

ANTHROPOLOGY. By J. E. Manchip White, pp. viii + 191. Philosophical Library, New York. 1955.

Manchip White has written a short popular introduction to anthropology of which almost half is given over to a discussion of physical anthropology. Two chapters, one on fossil man and human evolution and the other on race and studies of the living, give a well rounded substantial general discussion of our science for the layman, or beginning student in anthropology.

FPT

HEREDITY AND HEALTH AND MENTAL DISORDER. By Franz Joseph Kallmann, pp. 315. $6.00. W. W. Norton & Co., New York. 1953.

Sub-titled, ''Principles of Psychiatric Genetics in Light of Comparative Twin Studies,'' this book summarizes the findings of Doctor Kallmann who is the leading exponent and investigator using twin studies to determine the genetic component in psychiatric disorders. The book is not a full report on research done but rather the publication of a series of lectures (Salmon Lectures) delivered to the New York Academy of Medicine. As such, it reports the essence of Kallmann's findings and gives some supporting data as well as a very extensive bibliography; yet for those who want a report giving research data, Kallmann's other extensive writings should be consulted.

FPT

COLOR PREJUDICE IN BRITAIN. By Anthony H. Richmond, pp. xi + 184. Routlege and Kegan Paul Ltd., London, and Grove Press, New York. 1954.

Here is an account of the assimilation and adjustment of 345 West Indian Negroes who came to England between 1941 and 1943 and traces the relationships between this group and the English people over a period of approximately 10 years. While primarily dealing with the social aspects of this contact and revealing the nature of color prejudice and attitudes in England; it is especially valuable in pointing out the differences that exist in the social and physical environments of sub-groups in the same culture and the degrees of isolation that really exist in spite of apparent assimilation. Twenty-eight tables and charts are included.

FPT

THE FUNCTIONAL BODY MEASUREMENTS OF SCHOOL AGE CHILDREN. By W. Edgar Martin and Fred P. Thieme, pp. vii + 90. $1.00. National School Service Institute, 27 E. Monroe St., Chicago, Ill. 1954.

"A Handbook for Manufacturers, Design Engineers, Architects, and School Officials for Use in Planning School Furniture, Equipment and Buildings" is the sub-title of this report. Fifty-five measurements on 3,318 school age Michigan children are reported in 45 tables and graphs primarily arranged by age and by school grade. This study, done in March through June, 1954, was designed to obtain body dimensions of use in school room planning and in equipment design. Of special interest to physical anthropologists is the finding that the secular increases in some body dimensions are apparently continuing in the United States.

FPT

LOS INDIOS DE TEPOZTLAN (MEXICO). By Henry Field, pp. 87. University of Miami Press, Coral Gables. 1954.

A report of anthropometric data gathered from 211 males (164 adult and 11 juveniles from Tepoztlan, and 36 from de Gabriel Mariaca) is presented in a number of tables. In addition, comparative tables of mean anthropometric values for related Indian groups are given.

FPT

THE UNLEASHING OF EVOLUTIONARY THOUGHT. By Oscar Riddle, pp. ix + 414. $4.50. Vantage Press, New York. 1955.

"This book is not primarily philosophy nor science nor a report on a social inquiry. It is nevertheless a blend of those three things — with sustained accent on the third. In general, it is an account of the cultural impasse in which *available* evolutionary insight, useful or necessary to social progress and racial survival, is made *unavailable* to society by contemporary organized religion.'' The book is divided into two broad sections, the first dealing with what modern evolutionary thought is; and the second discussing the activities of the world's organized religions in preventing these concepts and findings to be effectively utilized by modern society. A thoughtful book written by an outstanding biologist on an exceedingly important, timely and emotion-loaded subject.

FPT

THE RACIAL AFFINITIES OF THE BAGANDA AND OTHER BANTU TRIBES OF BRITISH EAST AFRICA. By Lawrence Oschinsky, pp. vii + 188. 25/-net. Heffer & Sons Ltd. 1954.

Thirty-six anthropometric measurements taken on adult males from 19 sub-groupings of the Bantu, totaling 1,056 individuals are reported in this study; from 5 sub-groups of Nilotic and Nilo-Hamitic totaling 137 individuals, and from 50 Zanzibar Arabs. While reporting a significant volume of new data, this book primarily is a comparative study which attempts to place the Bantu in a racial taxonomy. All available anthropometric data on the various groups of related African natives as well as some blood group and sicklemia frequencies are considered and included in the extensive comparative tables which make up most of the book. Photographs and an extensive bibliography are included.

FPT

READINGS IN ANTHROPOLOGY. By E. Adamson Hoebel, Jesse D. Jennings, and Elmer R. Smith, pp. xiii + 417. $5.00 (Paperbound, $3.75). McGraw-Hill Book Company, Inc., New York. 1955.

Eleven selections are included on prehistory and physical anthropology out of a total of over 50 in this collection of articles chosen as supplementary reading for introductory courses in general anthropology. While the 11 articles are by outstanding workers in the field, they are mostly summary or popular discussions. It will be up to the instructor to ensure that the student will read the more basic articles which cover these and other interests in physical anthropology.

FPT

SCHOOL AND CHILD, A CASE HISTORY. By Cecil V. Millard, pp. xi + 219. $3.75. Michigan State College Press, East Lansing. 1954.

The unique quality of this book is the longitudinal description of the development, both physical and social, of one child. The analysis and discussion is in terms of this child compared to group norms and of general principles of child development.

FPT

BLOOD GROUPS IN MAN. By R. R. Race and Ruth Sanger, pp. xvi + 400. $7.50. Second Ed. Charles C Thomas, Springfield, Ill. 1954.

In this revised edition, *BLOOD GROUPS IN MAN* continues to be the outstanding work on what is known about blood groups. This includes the technique of their testing, the data defining modes of inheritance, methods of calculating gene frequencies, and all of the information pertinent to the understanding of each of the blood type reactions. This new edition, some 110 pages longer than the first one, has added new data gathered since 1950 as well as the most recent interpretations of these data. Each chapter of the 1950 edition has been revised and two new ones — on the *Kidd* groups and on linkage — have been added. Any anthropologist who hopes to keep abreast of the rapidly enlarging blood group knowledge should have this book plus Mourant's, THE DISTRIBUTION OF THE HUMAN BLOOD GROUPS.

FPT

ATLAS OF MEN. By W. H. Sheldon, pp. xvi + 357. $10.00. Harpers and Brothers, New York. 1954.

This most recent volume in the *Human Constitution* series is a pictorial and tabular presentation of the known somatotypes between the ages of 18 and 65. It is based on studies of 46,000 American males and gives not only their typical appearance and frequency, as typified in the Sheldonian somatotypic scale, but their place in a world of animal behaviors: insect, avian, marsupial and mammalian. We find for example that persons of somatotype 2–1–6 are ''Little male mosquitoes. Frail waifs of the night air, almost helpless, and they cannot even sting.'' We are not told how these thumb-nail sketches on the behavior of assorted animals, different for each of the somatotypes, relate to man; nor are we given the data which may conceivably relate it to man. Sheldon regards these sketches as "a valuable teaching prop," but fails to mention what student level is required.

In this volume, as in previous ones by this author, the reader must grapple with innumerable conclusions, largely unsupported by any published data, as to the relationship between somatotype and psychotype, whatever may be its animal equivalent.

FPT

ADVANCES IN GENETICS. VOLUME VI. Edited by M. Demerec, pp. ix + 485. Academic Press, Inc., New York. 1954.

The latest volume in this series contains 8 substantial contributions to genetic knowledge of which two are of special interest to physical anthropology. "Genetic Changes in Human Populations, Especially Those Due to Gene Flow and Genetic Drift" by Bentley Glass is important because he deals with a most fundamental anthropological problem. He shows how genetic data from field research investigations when set in the theoretical frame of population genetics can help show how the process of change occurs. Anthropologists who are tempted to use random gene drift as a *deus ex machina* to explain the variability in small populations should consult this article.

Another article, by Philip Levine, describes "The Genetics of the Newer Human Blood Factors." This is an account by an outstanding contributor to this field of the latest knowledge about the genetics of these many new blood type factors. One topic discussed by Levine is of special interest, particularly in relation to Glass's article, namely, gene loss due to morbidity from antigenic incompatability of the maternal and paternal genes affecting the offspring. Selective factors such as this rather than purely random effects are certainly also probable causes of much of the racial levels of differences between populations as well as differences at higher taxonomic levels.

FPT

THE BLOOD GROUP AND THE SECRETOR GENES OF THE STONEY AND SARCEE INDIANS OF ALBERTA, CANADA

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In previous papers, (Chown and Lewis, '53, '55), part of a continuing study under the aegis of the National Museum of Canada, we reported the blood group and secretor gene frequencies and the inheritance of these genes in the Blackfoot Indians of Alberta. The present paper reports the frequencies of these genes in the Stoney and Sarcee Indians.

The Stoney whose blood we tested are a remnant of the Assiniboine and live on a reserve centred around Morley, Alberta. According to Jenness ('34) this tribe, estimated at about 9000, was living in south-western Ontario around the Lake of the Woods and Lake Nipigon when contact was made by Whites early in the 17th century. From there they moved west, some to the north-west of Lake Winnipeg, some into the valleys of the Assiniboine and the upper Missouri Rivers. In at least the first two of these latter areas they associated and formed alliances with Cree Indians. Eventually in the latter part of the 19th century they were settled on reserves, about half around Fort Belknap in Montana, the remainder in Saskatchewan and Alberta. The group around Morley is the largest in Canada, but numbers only about 900. The Stoneys have then had contact with Whites for 300 years, fairly close contact for about 75 years. Miscegenation with Whites and with neighboring tribes, particularly Cree, has certainly occurred.

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The Sarcee according to Harrington ('40) are a part of the Sekenah-Beaver-Sarcee complex of the Athapascan-speaking people. The Sarcee moved south in prehistoric times and attached themselves for protection to the Blackfoot Confederacy, who looked upon them as their inferiors, if not as slaves. They numbered only about 700 when first discovered by Whites late in the 18th century, and now number only about 200. In the past 70 years a good deal of white blood has been introduced.

MATERIALS AND METHODS

Both blood and saliva specimens were collected each morning and tested the same afternoon and evening. The A, B, M, S, P, Rh, K, k, and Lu^a antigens were determined by saline suspensions in the capillary; s and Le^a by a short albumin method (Chown, Lewis and Bryce, '48); N, A_1 and *Henshaw* by saline suspensions in the open-well slide; Fy^a by indirect Coombs with final reading on a rocking slide. The Rh antigens were determined by the use of anti-C, C^w, c, D, E, and e. The two samples reacting as cdE were tested for the presence of the D^u antigen by the indirect Coombs method. The salivas were diluted 1:10, heated 10 minutes in boiling water, centrifuged and equal parts of the supernatant added to anti-H or anti-A serum. Gene and chromosome frequency analysis was carried out by the methods given by Mourant ('54), that for Rh chromosomes being the 5 sera method, pages 224–226, for $MNSs$ of the Stoney the 4 serum method, page 221. The Rh chromosome frequency analysis in our earlier paper (Chown and Lewis, '53) was carried out by the method of Race and Sanger ('50).

RESULTS

The results for the ABO, $MNSs$, P, Rh and Fy systems are set out in tables 1 to 14.

The *Kell* system. One hundred and sixty-two Stoney were tested with anti-K and found to be K—. One hundred and

TABLE 1

The ABO groups of the Stoney

GROUP	NUMBER	FREQUENCY OBSERVED	*Gene frequencies*	
O	114	.7037	O	.8389
A_1	48	.2963	A_1	.1611
	162	1.0000		1.0000

TABLE 2

The MN groups of the Stoney

GROUP	NUMBER	FREQUENCY OBSERVED	FREQUENCY EXPECTED	NUMBER EXPECTED	*Gene frequencies*	
MM	114	.7862	.7853	113.87	M	.8862
MN	29	.2000	.2017	29.25	N	.1138
NN	2	.0138	.0130	1.88		1.0000
	145	1.0000	1.0000	145.00		

TABLE 3

The Ss groups of the Stoney

GROUP	NUMBER	FREQUENCY OBSERVED	FREQUENCY EXPECTED	NUMBER EXPECTED	*Gene frequencies*	
SS	7	.0483	.0634	9.19	S	.25175
Ss	59	.4069	.3767	54.62	s	.74825
ss	79	.5448	.5599	81.19		1.00000
	145	1.0000	1.0000	145.00		

TABLE 4

The MNSs groups of the Stoney

GENOTYPE	NUMBER	FREQUENCY OBSERVED	FREQUENCY EXPECTED	NUMBER EXPECTED	*Chromosome frequencies*	
MSMS	4	.0276	.0313	4.54		
MSMs	44	.3034	.2510	36.40		
MsMs	66	.4552	.5030	72.94		
MSNS	2	.0138	.0265	3.84		
MSNs	14	.0966	.0138	2.00	MS	.1770
MsNS			.1061	15.38	Ms	.7092
MsNs	13	.0896	.0553	8.02	NS	.0748
NSNS	1	.0069	.0056	0.81	Ns	.0390
NSNs	1	.0069	.0058	0.84		1.0000
NsNs	0	.0000	.0015	0.22		
	145	1.0000	.9999	144.99		

TABLE 5

The Rh groups of the Stoney

PHENOTYPE	POSSIBLE GENOTYPE	NUMBER	FREQUENCY OBSERVED	FREQUENCY EXPECTED	NUMBER EXPECTED
CcDEe	R_1R_2 R_2R_0 R_zr R_1R''	53	.3419	.3706	57.44
CCDee	R_1R_1	41	.2645	.2346	36.36
ccDEE	R_2R_2 R_2R''	25	.1613	.1421	22.03
CcDee	R_1R_0 R_1r	14	.0903	.1151	17.84
ccDEe	R_2R_0 R_2r R_0R''	14	.0903	.0842	13.05
ccDee	R_0R_0 R_0r	1	.0065	.0047	0.73
CCDEe	R_1R_z	3	.0193	.0182	2.82
CcDEE	R_2R_z $R''R_z$	1	.0065	.0142	2.20
ccddee	rr	2	.0129	.0094	1.46
ccddEe	$R''r$	1	.0065	.0056	0.87
ccddEE	$R''R''$	0	.0000	.0009	0.14
CCDEE	R_zR_z	0	.0000	.0004	0.06
		155	1.0000	1.0000	155.00

Chromosome frequencies	
CDe (R_1)	.4844
cDE (R_2)	.3488
cDe (R_0)	.0219
CDE (R_z)	.0188
cdE (R'')	.0292
cde (r)	.0969
	1.0000

TABLE 6

The Pp groups of the Stoney

GROUP	NUMBER	FREQUENCY OBSERVED	*Gene frequencies*	
P +	138	.8903	P	.6688
P —	17	.1097	p	.3312
	155	1.0000		1.0000

TABLE 7

The Duffy groups of the Stoney

GROUP	NUMBER	FREQUENCY OBSERVED	*Gene frequencies*	
Fy(a +)	137	.8839	Fy^a	.6593
Fy(a —)	18	.1161	Fy^b	.3407
	155	1.0000		1.0000

TABLE 8

The ABO groups of the Sarcee

GROUP	NUMBER	FREQUENCY OBSERVED	*Gene frequencies*	
O	49	.5158	O	.7182
A_1	46	.4842	A_1	.2818
	95	1.0000		1.0000

TABLE 9

The MN groups of the Sarcee

GROUP	NUMBER	FREQUENCY OBSERVED	FREQUENCY EXPECTED	NUMBER EXPECTED	*Gene frequencies*	
MM	83	.8738	.8679	82.45	M	.9316
MN	11	.1158	.1274	12.10	N	.0684
NN	1	.0105	.0047	0.45		1.0000
	95	1.0000	1.0000	95.00		

TABLE 10

The Ss groups of the Sarcee

GROUP	NUMBER	FREQUENCY OBSERVED	*Gene frequencies*	
S +	64	.6737	S	.4288
S —	31	.3263	s	.5712
	95	1.0000		1.0000

TABLE 11

The MNSs groups of the Sarcee

(Tested with anti-*M*, *N*, and *S*.)

GROUP	NUMBER	FREQUENCY OBSERVED
MMS	56	.5895
MMs	27	.2842
MNS	8	.0842
MNs	3	.0316
NNS	0	.0000
NNs	1	.0105
	95	1.0000

TABLE 12

The Rh groups of the Sarcee

PHENOTYPE	PROBABLE GENOTYPE	NUMBER	FREQUENCY OBSERVED
CcDEe	R_1R_2 R_1R''	27	.3034
CCDee	R_1R_1	22	.2472
ccDEE	R_2R_2 R_2R''	19	.2135
CcDee	R_1r	12	.1348
ccDEe	R_2r	8	.0899
ccddEe	$R''r$	1	.0112
		89	1.0000

TABLE 13

The Pp groups of the Sarcee

GROUP	NUMBER	FREQUENCY OBSERVED	*Gene frequencies*	
P +	69	.7753	*P*	.5260
P —	20	.2247	*p*	.4740
	89	1.0000		1.0000

nine Stoney were tested with anti-k and found to be $k+$. Ninety-five Sarcee were tested with anti-K; *all were* $K-$.

The *Lutheran* system. Eighty-eight Stoney were tested with anti-Lu^a; all were Lu(a —).

The *Lewis* system. One hundred and fifty-five Stoney and 89 Sarcee were tested with anti-Le^a; all were Le(a —).

The *Secretor* system. Forty-two Group A_1 Stoney and 45 Group A_1 Sarcee were tested and all found to be secretors of A substance. Eighteen Group O Stoney were tested and all found to be secretors of H substance.

The *Henshaw* system. Ninety-six Stoney were tested with anti-*Henshaw;* all were negative.

TABLE 14

The Duffy groups of the Sarcee

GROUP	NUMBER	FREQUENCY OBSERVED	*Gene frequencies*	
Fy(a +)	82	.9213	Fy^a	.7195
Fy(a —)	7	.0787	Fy^b	.2805
	89	1.0000		1.0000

DISCUSSION

Matson ('38) found 49 "pure-blood" Stoney at Morley to be O 36, A 13, gene frequencies O .8571, A .1429; frequencies for our sample, not selected for "purity", O .8389, A .1611. Murray ('52) using anti-C, D, E and c but not e found 57 Stoney to have estimated Rh chromosome frequencies of cDE .5193, CDe .4388, CDE .0419, the remaining chromosomes not being isolated; frequencies for our sample cDE .3488, CDe .4844, CDE .0188, cde .0969, cDe .0219, cdE .0292. Our figure of .0969 for cde suggests that our sample contained more individuals with an admixture of White blood than did hers. This probability is supported by the fact that in our sample CDe > cDE whereas in other Indians of Western Canada that we have examined, except in some Cree in close contact with Whites and in Blackfoot, about $\frac{1}{6}$ of whose blood group genes we estimated to be of White origin (Chown and Lewis, '53), CDe < cDE. The data of Matson, Koch and Levine ('54) are of interest here: Their cDE:CDe gene frequency ratios, rounded to whole numbers, and their *cde* frequencies in Chippewa Indians of Minnesota were:

	cDE	:	*CDe*	*cde*
''Full-Blood''	53	:	34	.0803
> ¾ Indian	42	:	38	.1087
< ¾ Indian	36	:	42	.1589

Although, as evidenced by the *cde* frequency of .0803, their ''full-blood'' Indians were almost certainly not full-blood, nevertheless the high cDE: CDe ratio in this group and the falling ratio as Indian genes are replaced by White illustrate well the value of the ratio in blood group gene studies of Indian populations.

Matson ('38) found 12 ''pure-blood'' Sarcee to be *O* 5, *A* 7. Grant ('36) reported 40 Beaver, close blood relatives of the Sarcee as being *O* 21, *A* 19, gene frequencies *O* .7246, *A* .2754, compared to ours for the Sarcee of *O* .7182 *A* .2818. There are no other blood group studies on the Sarcee or Beaver.

ACKNOWLEDGEMENT

We are happy to acknowledge the continued support of the National Museum of Canada through Dr. F. J. Alcock and Dr. Douglas Leechman, and the great assistance given us on the reserves by Mr. G. H. Gooderham, Inspector of Indian Agencies, and Mr. J. Cousineau, Indian Agent at Morley. We are deeply indebted to Dr. A. E. Mourant for the anti-Henshaw and Lu^a; Dr. Philip Levine for anti-s; Drs. Peter Vogel and Richard Rosenfield for anti-S; Dr. M. Shapiro for anti-k.

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A RECENT DISCOVERY IN HUMAN PALEONTOLOGY: ATLANTHROPUS OF TERNIFINE (ALGERIA)[1]

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TEN FIGURES

Since 1838 when Boucher de Perthes found the first worked stones attributable to a human being in the high terraces of the Somme valley, near Abbeville, prehistoric discoveries have been extended gradually throughout the Old World in Europe, Asia and Africa. Everywhere, a succession of industries has been gradually found, extending through various stages of the Quarternary, attesting that various human groups succeeded one another over a period which can now be estimated at nearly a million years.

Evidences of industries left by these vanished populations are abundant in caves or in surface sites but, skeletal remains which could reveal the physical nature of those who made these industries are rare. The best known of the ancient stone-workers were the most recent. First known were those who lived between 15 and 30 thousand years ago and who left everywhere in caves in Europe and Africa a varied workmanship in stone and bone, accompanied sometimes, as in the famous sites of Dordogne and Spain, by engravings and polychrome paintings, testifying to their artistry and advanced mentality. These men, physically like modern men, form the group known to anthropologists as Cro Magnons.

Then, after the close of the last century, men were known who, at the beginning of the last glacial period, were the makers of industries called Levalloiso-Mousterian. These men, who lived between 50 and 150 thousand years ago, constitute the Neanderthalian group and their remains have been found in Europe, the Near East and Africa. While already near present mankind, they differed in a number of characters of the skull and extremities; but, they were distinguished especially by a more primitive brain and a more primitive mentality as shown by the relative simplicity of their workmanship.

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[1] This paper was translated from the French by F. Clark Howell.

Otherwise, nothing has been known of the older artisans of the most ancient industries, known to prehistorians as biface or hand-axe or Chelleo-Acheulean industries, those which precisely enabled Boucher de Perthes to establish the foundations of prehistory.

These industries are very widely distributed in the Old World, however, and numerous sites in Europe, in Asia, and especially in Africa have provided important sequences. Moreover, they correspond chronologically to a period of prolonged duration, beginning about 500,000 years ago and persisting until the last glaciation. The physical appearance of the makers of these industries has been indeed one of the most important problems in human paleontology and one of which the solution has been heretofore in suspense.

This problem was recently resolved by a discovery in North Africa where in June, 1954, with the assistance of R. Hoffstetter (Maître de Recherches du Centre National de la Recherche Scientifique), I excavated two human mandibles associated with an abundant Chelleo-Acheulean industry from the site of Ternifine, near Mascara in Algeria (Arambourg, '54a, '54b; Arambourg and Hoffstetter, '54). The industry, as well as the numerous remains of associated fossil animals, permit dating the Ternifine site to the beginning of the Middle Pleistocene, about 500,000 years ago.

The site of Ternifine

The site of Ternifine has attracted the attention of prehistorians and paleontologists for a long time (cf. Dalloni, '40). It is an old sand pit (figs. 1–4) opened about 1872 when the village of Palikao was founded, 17 kilometers southeast of Mascara (Algeria). Since that time, the presence of numerous animal bones and worked stones has been recognized; but, the proximity of a Mohammedan cemetery, at the top of a sand dune, soon prevented work at the site in spite of all the interest aroused by the studies of Pomel (1886, 1888a, 1888b; Pallary, 1887) on the fossil fauna collected there. It was only in 1931, as a result of a study of the site, that I recognized that here was erosion of an ancient lake basin filled-in with sands during a very old part of the Quarternary when the level of the surrounding country was 15 meters higher. The exploitation of the sand pit had stripped only the upper levels of the site, those found above the present level of the plain; but, the deeper levels, which rested on the floor of the ancient basin and were covered by water, remained intact and could prove extremely rich. For this reason and based on these observations, I undertook last year to dig the deeper buried levels, pumping out the overlying water. In this way, important results could be obtained very quickly.

The fauna

The fauna associated with the human remains includes: hippopotamus; an elephant *(E. atlanticus* Pomel) near *E. africanus,* of which a skull was discovered (figs. 3–4); a rhinoceros near, but not identical to *Rh. simus;* a zebra *(Equus mauritanicus* Pomel); numerous ruminants including giraffe and camel *(C. thomasi* Pomel); various antelopes *(Alcelaphus, Taurotragus, Gorgon, Oryx, Gazella,* etc.); and carnivores *(Hyaena crocuta, striata; Felis leo,* etc.). To this series it is necessary to add three particularly important elements: a *Machairodus;* a giant phacochoerine of the *Notochoerus* group, hitherto peculiar to the oldest stages of the Pleistocene in East and South Africa; and, a giant baboon close to the giant fossil forms of those same regions. These three elements are themselves sufficient to give the Ternifine site an archaic character which place it at the base of the Middle Pleistocene (Kamasian of other African authors).

The industry

The industry which accompanies this fauna includes more than a hundred pieces in quartzite, silcrete or limestone with very rare flint. There are primitive rostroid (high-backed) bifaces, cleavers characteristic of the African Pleistocene, and large flakes of Clactonian type (figs. 5–6). All these specimens are very rough and were worked exclusively with a stone-hammer (stone-on-stone technique). From the opinion of specialists, this industry characterizes the beginning of the Middle Pleistocene; it is paralleled by that of the high fluviatile terraces in Europe and by the oldest bifacial industries in Africa.

The evidence of paleontology and prehistoric archeology agrees in dating the Ternifine site irrecusably to the beginning of the Middle Pleistocene, a fact which needs no further emphasis as to its importance.

The human remains

The study of the human remains is in progress; but, it is possible already to establish the essential features of the morphology.

One of the jaws is almost complete with all the dental series except for canines and three incisors (figs. 7–8). This remarkably robust specimen probably belonged to a male. The second, smaller jaw is probably female; it comprises only the left half with the dental series lacking incisors and canine (figs. 9–10). In spite of their differences, these two specimens are remarkably robust. Their inferior borders, especially in No. 1, are expanded in a *torus marginalis* which is remarkably thick and comparable, with the exception of absolute dimensions, to that of *Meganthropus* of Java. The symphysis is retreating; the lingual surface slightly concave and lacking a torus; a small geniohyoid fossa is visible in the female specimen (No. 2).

The digastric fossae extend along the ventral border of the symphysis and a portion of the lingual surface. Consequently, this form differs from that of Peking, Java and Heidelberg man but it appears to conform to that of *Meganthropus.*

The ramus of the female specimen is low and broad as in Peking man, and a bit more gracile than in the Mauer jaw.

The dental arcade forms a parabolic arc which may be superimposed almost on that of *Sinanthropus* Gl, and the incisor-canine series occupies almost the same proportions.

The low, broad molars are macrodont and taurodont. The premolars, as large as those of the Pithecanthropines, have cingula on their buccal surfaces. The molars are 6-cusped; the grooves separating the cusps are of the Dryopithecus Y-type but are attenuated as in *Sinanthropus.* The occlusal surfaces of the teeth bear secondary crenulations as in certain specimens of *Sinanthropus.*

On the whole, the new fossils are very closely related to the Asiatic *Pithecanthropus* and *Sinanthropus.* They also exhibit, notably in their robustness and massiveness, as well as in the persistence of a genioglossal fossa, some features reminiscent of the australopithecines, *Telanthropus* particularly, in which, however, the dental morphology is more primitive. Nevertheless, they cannot be identified exactly with either *Pithecanthropus* or *Sinanthropus* or *Telanthropus;* therefore, I have assigned to them the provisional name, *Atlanthropus mauritanicus.*

CONCLUSIONS AND SUMMARY

1. This new link in the human series finally provides the answer awaited by prehistorians of the nature of the creatures who made the Chelleo-Acheulean biface industries, and who are disclosed to have been *Euhominidae* of the Pithecanthropine group.

2. It confirms the human nature of the latter which certain authors have contested.

3. The presence of these creatures in North Africa and the extension throughout the continent of bifacial industries make this the only part of the world in which all the human

paleontological series after the australopithecines, and with Neanderthalians and *Homo sapiens,* is represented in a regular stratigraphic sequence.

4. Added that Africa seems to have been, since the Oligocene, a center of evolution and dispersal for the whole primate group, and especially for the catarrhines, this continent ranks, as I have long maintained, of primary importance for research in human paleontology.

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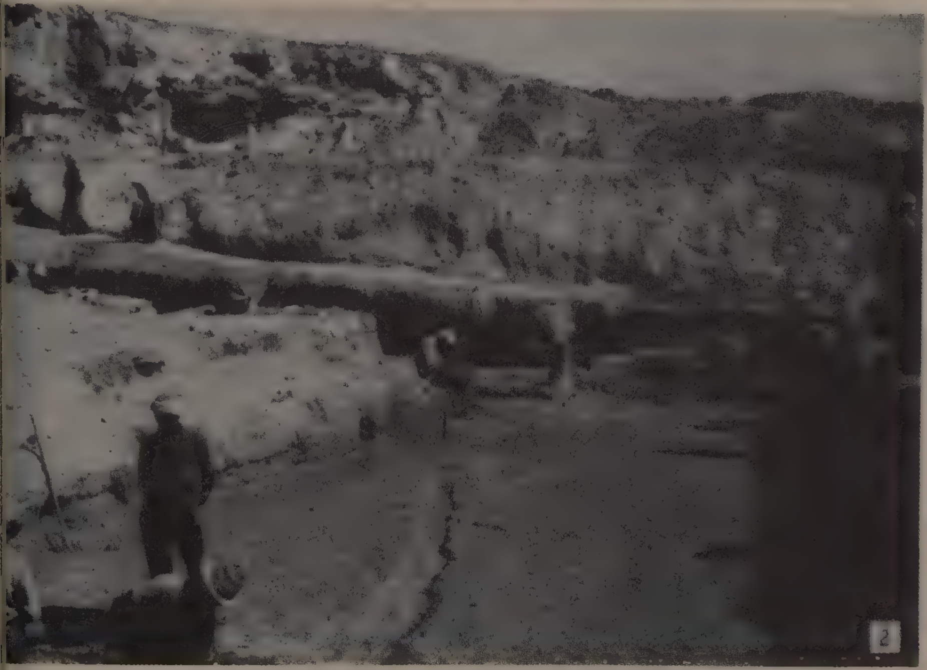
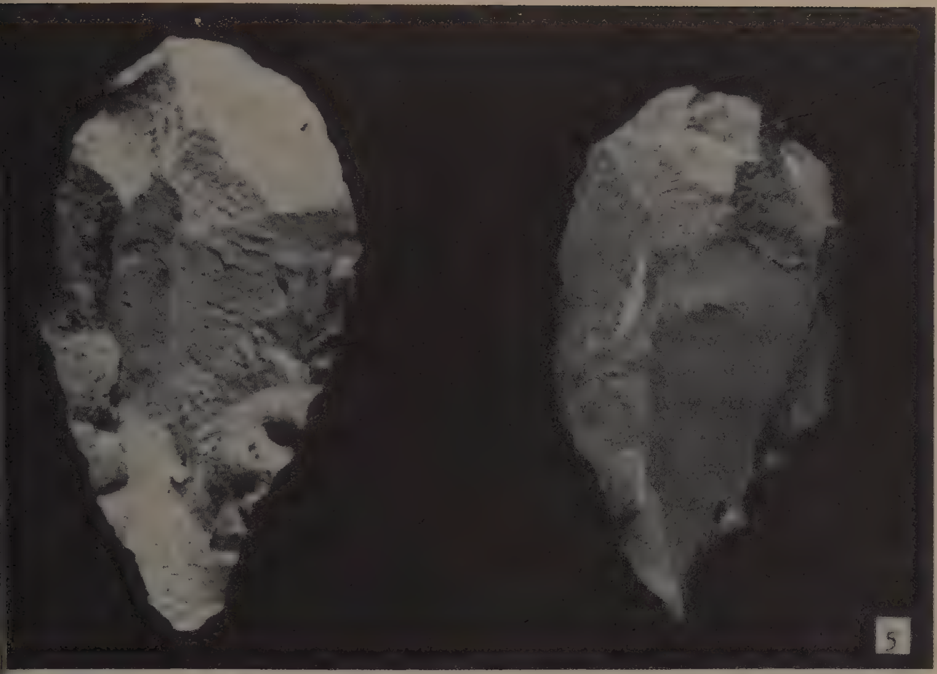


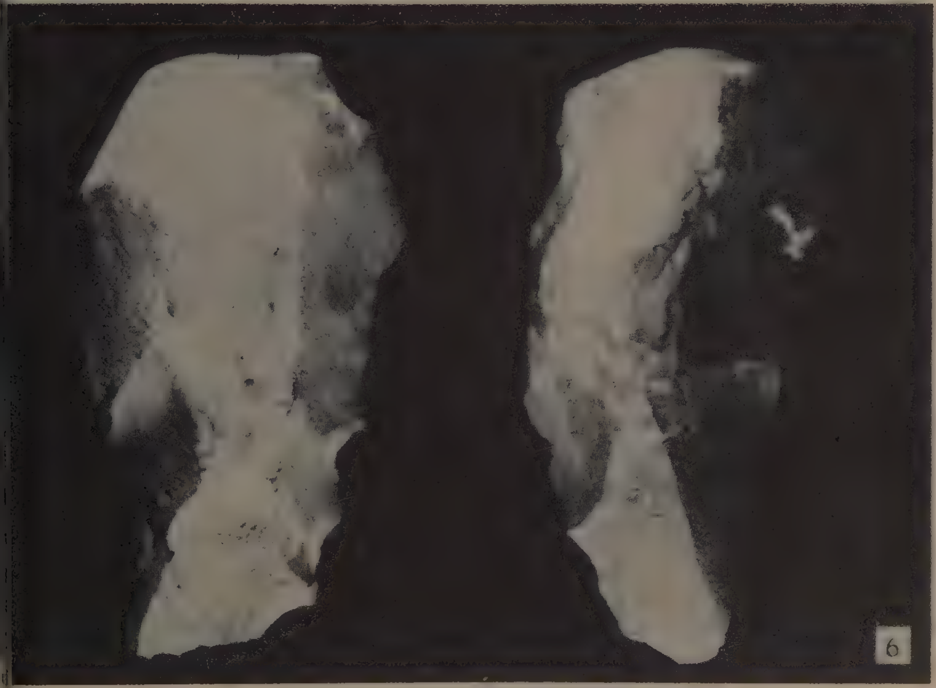
1 Water rising in the Ternifine sand pit after the excavations in 1954.

2 General view of the 1954 excavations at Ternifine. The stake (near the seated figure) marks the point where the first human mandible was found.

3 The south trench at Ternifine and the locality where the second human mandible was found.

4 Removal of an *Elephas atlanticus* skull from the end of the south trench at Ternifine.





5 Chelleo-Acheulean hand-axes from Ternifine.

6 Chelleo-Acheulean cleavers from Ternifine.

THE EVOLUTION OF THE HUMAN ILIUM

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SEVEN FIGURES

INTRODUCTION

The australopithecines of South Africa are commonly regarded as bipeds. If the Meganthropus jaw-fragment from Java is included in this group, the case may be made that these forms lived throughout the Old World tropics. At least some of them appear to be of Villafranchian age (Oakley, '54), and so may be representative of the kinds of animals that are directly ancestral to man. If this view of human evolution is considered reasonable, or at least possible, then the evolution of bipedal locomotion seems to have preceded other uniquely human attributes. It appears quite probable that our ancestors walked first, and subsequently became large-brained, tool-using humans.

The reason for asserting the priority of bipedal locomotion rests primarily on the ilia of the australopithecines. The Sterkfontein, Makapansgat, and Swartkrans ilia appear so human that many anthropologists regard them as indicating bipedal locomotion, thus differentiating the australopithecines from the apes (Dart, '48; Broom, '50a, '50b; Heberer, '51; Clark, '55a). Zuckerman ('54) seems alone in his view that the australopithecines might be ancestral to the great apes.

Prior to the discovery of the australopithecines, many investigators had called attention to the unique features of the human pelvis, emphasizing the shortening, bending back, and widening of the ilium as essential features for bipedal locomotion of the human sort. However, these studies, based on the anatomy of living apes and men, could give no knowledge of the actual stages through which a generalized quadrupedal pelvis might have passed in evolving into a bipedal one. Clark ('55a) has rightly stressed that the australopithecines, in a general way, confirm the expectations of students of comparative primate anatomy. Although this is true, no one anticipated a rather long, ape-like ischium combined with a short, wide ilium. Furthermore, no one suspected that the backward bending and widening of the ilium preceded the development of an S-shaped iliac crest, definition of two gluteal planes, and strong development of the iliac tubercle.

Although agreeing with those who maintain that the australopithecine ilium indicates bipedal locomotion and affinity with man, one wonders about the functional significance of the differences between the australopithecine ilium and that of man. Were the australopithecines fully erect? Are the curved iliac crest, tubercle, and gluteal planes significant for bipedal locomotion? If so, how might this significance be analyzed?

The pelves of the australopithecines have already been compared to that of man with regard to general shape (Dart, '49; Broom and Robinson, '50, '52), by outline (Clark, '55b), and biometrically (Zuckerman, cited '54, but data unpublished). Additional knowledge may be gained by an analysis of the internal structure of the pelvis in apes and man, and by relating the differences of internal thickness and organization to muscle action and locomotion. This paper is a preliminary attempt at analyzing the inner form of the innominate bones of man and chimpanzee in a way which will help in the interpretation of the fossil australopithecines. If the function of the iliac tubercle can be determined, then its presence in man and absence in chimpanzee, should be understandable in terms of each animal's way of life. If the significance of the presence and absence of this structure can be understood in living forms, then it should be possible to make much better inferences about the meaning of the intermediate condition seen in the fossils.

With this purpose in mind, the innominate bones of man and chimpanzee were compared with regard to their internal organization as shown by the distribution of thick and thin bone and their split-line pattern. In this paper, the bony pattern is related to muscle function and, in turn, to locomotion. Finally, the understanding of the mechanism of balance, which resulted from this analysis, is applied to the problem of the interpretation of the locomotion of the australopithecines. The suggestion is that their adaptation to the human type of bipedal locomotion was not complete, that they were forms in transition, and that the change in locomotion from ape to man *may* have taken place during the Villafranchian period.

MATERIALS AND METHODS

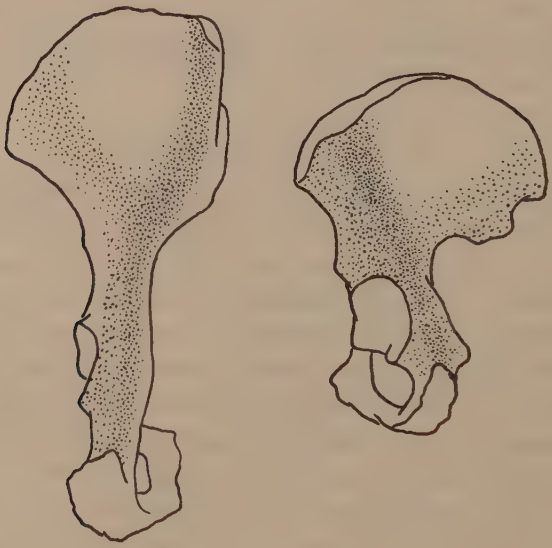
Split-line preparations were made of 4 chimpanzee and 8 human innominate bones. This technique, first described by Benninghoff ('25) and improved by Seipel ('48) and Tappen ('54), consists in placing bone in a ten per cent solution of HC1 until the bone is soft enough to allow easy penetration of a teasing needle. The puncture results in a split, which may be lengthened by carefully guiding the needle in the direction of natural splitting. Properly decalcified bone will only split in one direction, and the pattern cannot be altered in artificial directions. The splits are marked by india ink. This may be done by dipping the needle in the ink prior to making the split, or the ink may be added afterward. The prepared bones are best preserved dry, since they tend to discolor and are apt to mold if stored in fluid.

Decalcification occurs more rapidly in thin regions. Since chimpanzee innominate bones vary greatly in thickness, the thin parts of the bones may be completely destroyed before the thickest parts are sufficiently decalcified. Therefore, the illustrations of the split-line patterns are composites of the pattern seen at successive stages. Although the human innominate bone is also of variable thickness it may, with care, be decalcified and mapped in one operation.

No attempt was made to analyze small individual differences in this study. This paper deals with the major patterns which are characteristics of the species and lie far beyond the range of individual variation.

OBSERVATIONS

Areas of thick and thin bone. Figures 1 and 2 show the distribution of thick and thin bone in the innominate bones of chimpanzee and man. In the chimpanzee, the thick bone forms a column from the posterior superior spine of the ilium to the tuberosity of the ischium. The ala of the ilium is much thinner, although there is a slightly thickened portion near the anterior margin of the bone. In man, the region from the sacro-iliac articulation to the acetabulum is also thick, but the external table of the bone leading from



1 2

Figs. 1 and 2 Areas of thick and thin bone in chimpanzee and human innominate bones. Heaviness of stippling indicates degree of thickening in the outer table of the bone.

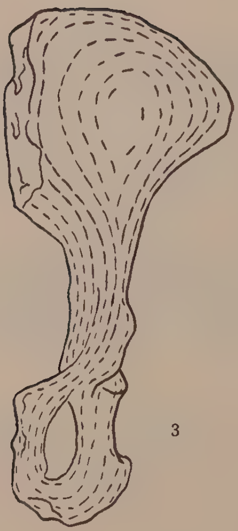
the iliac tubercle to the region of the acetabulum is more markedly thickened. This column of bone demarcates the two gluteal planes of the human bone and adds to the curvature of the iliac crest.

Both animals have a thickened region connecting the sacro-iliac articulation to the margin of the acetabulum. The difference lies in the extreme thickening in the outer table from the tubercle to the acetabulum in man. These differences were first noticed because of the retardation of decalcification of the thick areas, and were later checked by sectioning the bones.

Split-line pattern. The split-line patterns of the chimpanzee bone are shown in figures 3 and 5. The pattern on the inner and outer surfaces are nearly identical. This indicates that the internal organization of the bone is similar on both surfaces. In man, figures 4 and 6, the patterns on the two surfaces are quite different. The pattern on the inner surface closely corresponds to that of the chimpanzee, but on the outer surface several differences are noted when the two animals are compared. In chimpanzee, the major tracts of split-lines are oriented from the sacro-iliac articulation to the ischial tuberosity and from the superior margin of the acetabulum to the iliac crest. This same orientation holds for the inner surface of the human bone.

On the gluteal surface (outer) of the human ilium, *three* distinct tracts of split-lines are discernible. The first is oriented between the anterior superior spine and the superior margin of the acetabulum. The second runs from the sacro-iliac articulation around the greater sciatic notch to the ischial tuberosity. The third and unique tract of split-lines, begins immediately inferior to the iliac tubercle and runs downward to the posterior margin of the acetabulum.

This column of split-lines running from the tubercle to the acetabulum corresponds to the thickened bone which lies in exactly the same region of the ilium. Whether examined by split-line or by thickness, the same structural pattern is apparent.



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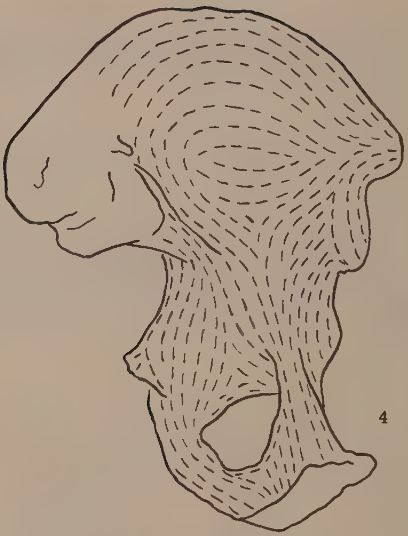

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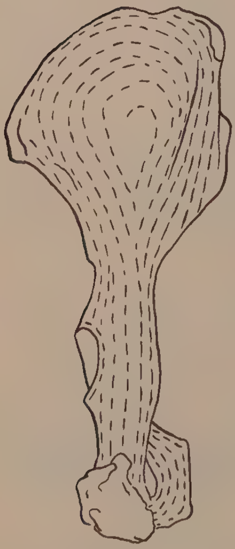

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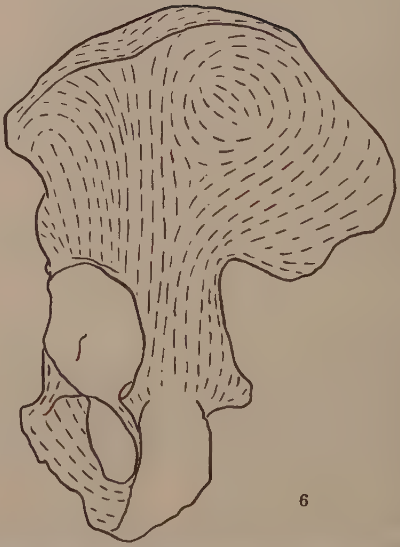

6

Split-line patterns of chimpanzee and human innominate bones.

Fig. 3 Chimpanzee iliac (inner) surface.

Fig. 4 Human iliac surface.

Fig. 5 Chimpanzee gluteal (outer) surface.

Fig. 6 Human gluteal surface. Note over-all similarity of two surface mappings in chimpanzee and marked differences in man.

Muscles. The thickened outer table of bone which lies between the sacro-iliac articulation and the acetabulum, with the corresponding tract of split-lines, common to both man and chimpanzee, obviously serves the function of connecting the lower extremity and the sacrum. However, the thickened column of bone with its characteristic tract of split-lines, which runs from the tubercle to the acetabulum, in man only, is not related to weight-bearing nor to abdominal musculature. It is related to the musculature of the hip.

In man, the gluteus maximus muscle is a large muscle arising from the posterior superior margin of the ilium and lateral extent of the sacrum and inserting into the iliotibial band of the fascia lata and into the gluteal tuberosity between the vastus lateralis and adductor magnus muscles on the lateral aspect of the thigh.

In the chimpanzee, the gluteus maximus muscle is small and has no origin from the ilium. It lies primarily lateral to the greater trochanter of the thigh and is, in the main, an abductor of the leg as are the other two gluteal muscles of the chimpanzee. All three gluteal muscles act primarily as abductors of the chimpanzee thigh. In man, on the other hand, the bending back and shortening of the ilium results in an altered position, and thus, action of the major gluteal muscle. The gluteus maximus muscle lies behind the femur and no longer acts primarily as an abductor, but rather as an extensor (Washburn, '50, '53). The gluteus medius and gluteus minimus muscles are still lateral to the thigh; the more vertical fibers of these two fan-shaped muscles run directly downward from the region inferior to the iliac tubercle to the greater trochanter of the femur.

These *two* human muscles have the function of all of the gluteal muscles of the chimpanzee, abduction and rotation of the thigh. They are the muscles which play the major role in shifting the body weight from one foot to the other in walking and in standing erect. These muscles are crucial for balance. Figure 7 shows the bone-muscle relationships of the human gluteal area. The importance of the two gluteal

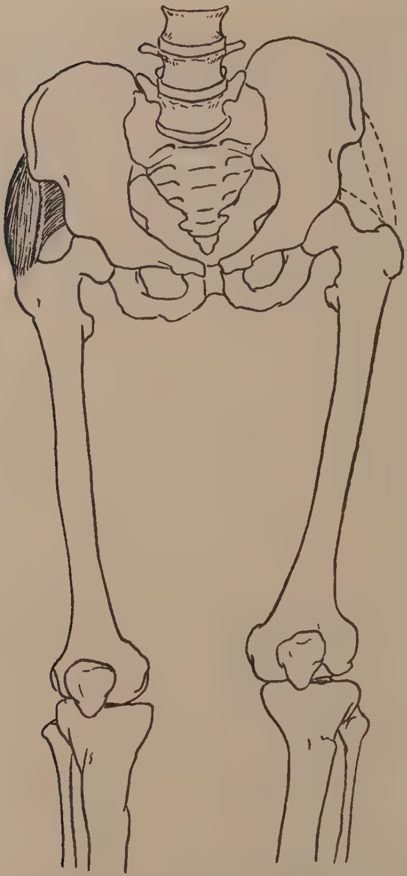

Fig. 7 Diagram of the action of gluteus medius and gluteus minimus in human locomotion. The body weight is supported on the right foot. The left leg and foot are raised preparatory to stepping off on the left foot. The contracture of the right gluteal musculature prevents the body from slumping toward the unsupported side.

muscles in aligning the trunk above the supporting leg and foot and in maintaining balance is readily apparent.

DISCUSSION

The changes that took place during the evolution of the human pelvis are far more complicated than is gathered from an examination of the external form and shape of the bones. The internal structure of the bones has changed as well, as shown by the distribution of thick and thin regions and the split-line tracts. All these changes are related to changed patterns of behavior.

An examination of figure 7 shows the relationship of the gluteus medius and minimus muscles to the structures under consideration. It is seen that a line projected downward through the tubercle would pass through or close to the greater trochanter of the femur. Elftman ('54) in his discussion of the functional structure of the lower limb stresses that one of the key functions of the hip musculature is control of the lateral stability of the body. An individual standing on one foot, about to step off on the other, must align the parts of his body so that the center of gravity of the whole is above the area of support provided by the foot. Because of the lateral projection of the hip joint in relation to the mid-line of the body, the trunk and opposite unsupported leg have a tendency to slump toward the unsupported side. Contraction of the gluteus medius and minimus muscles on the supported side, counteract this tendency and maintain the erectness of the body as weight is shifted from one foot to the other in normal walking. The development of the iliac tubercle and pillar is directly related to this balance of the body.

Sections through the bone in this region have shown that it is an area of strong, heavily reinforced bone, directly related to the muscles used for balance in standing and bipedal locomotion. The chimpanzee, an essentially quadrupedal animal on the ground, lacks these structures for balance.

The pattern of behavioral change associated with bipedal locomotion explains the differences in the development of the iliac-tubercle, -pillar, -crest and in the split-line orientations characteristic of the human innominate bone. The pelves of the australopithecines show that selection effected various parts of the pelvis at different times. It now seems clear that the widening, shortening, and bending back of the ilium came first; changes in the structure of the ilium in the region of the tubercle and pillar were secondary, yet probably prior to modifications in the ischial ramus and tuberosity. It is still not quite clear why the human type of ischial ramus and tuberosity is advantageous for a biped. Waterman ('27) states that a short lever arm insures better precision of action, and Clark ('55a) suggests that the high position of the ischial tuberosity enhances the extensor action of the hamstring muscles in full extension of the hip.

This study suggests that the australopithecines, lacking a well-developed iliac tubercle and pillar, could not balance as well as man. The inference is that they were still in the process of adapting to the orthograde progression and what is seen in these fossils is neither the stable condition of the great apes (whose locomotor adaptation appears to have been essentially the same for millions of years, Clark, ibid.), nor that of man whose posture and progression may have been stabilized in its present form by the middle of the Pleistocene. The australopithecines may represent a transitional stage of bipedal adaptation that never reached its culmination. Or, they may represent a stage that developed into man.

Many anthropologists believe that man's locomotor adaptation preceded the enlargement of the brain and modification of the face. This belief rests on the evidence that the femora associated with Java Man (Weidenreich, '38), Peking Man (ibid.), Rhodesian Man (Morant, '28), and the tibia from Ngandong (Weidenreich, '38), are all more anatomically modern than their skulls. It is easy to separate the skulls of a Java or Peking Man from the early representatives of anatomically modern man, but their limb bones are within the range of variation of living populations. (It is true that the limb bones of the Classic Neandertals, with their large articular surfaces and short radii and tibiae, are peculiar [Weidenreich, '43], but these are probably racial features and do not offer any clue to the anatomic conditions of more remote ancestral forms [Howell, '53].)

Unfortunately, no pelves are known from the middle Pleistocene, but judging from the early femoral evidence and from the fact that the pelves associated with the Mt. Carmel population (McCown and Keith, '39) are essentially human in their details, there seems little reason to suppose that the pelves of middle Pleistocene men were any different, or to doubt that the lomomotor adaptation had already occurred prior to the changes in the brain and face.

If it is believed that man was differentiated from the apes first in his way of locomotion, it is not contradictory to assert that a form is a part of the hominid radiation, and *still* may be ape-like in the majority of its features. If bipedal locomotion marks the beginning of peculiarly human evolution, then the origin of man will be reflected first in the pelvis. The combination of features seen in the australopithecines may be very close to such a hypothetical animal, ape-like in brain size and much of their anatomy, but already starting to move bipedally on the ground.

At this postulated stage of hominid evolution, it would be quite difficult to separate the diverging pelvic types since the first stage of pelvic change is marked by the progressive shortening and bending back of the ilium, accompanied by changes in the musculature permitting bipedal locomotion. The second stage of modification would be characterized by the beginnings of the iliac tubercle and pillar permitting an improvement in balance. Finally, the gradual shortening of the ischium and modification of its tuberosity would result in the unique human pelvis.

This sequence of change would represent the pelvic adaptations for bipedal locomotion, but there would also be concomitant modifications of other parts of the body in response to this changed behavioral complex. It cannot be expected that selective pressures operating on other functional units of the body would remain the same during, or after, this major adaptation. With the attainment of erect posture, the use of tools became a possibility and this changed the whole subsequent course of human evolution.

The techniques utilized in this study offer a method of checking the conclusion that the australopithecines were adapting to bipedal progression. The morphological details of the human ilium that are all important for balance, the iliac tubercle and pillar, may be discernible in these fossils. A familiarity with the split-line technique and its results often enables the investigator to recognize the patterns of organization in unprepared bones. For example, some untreated bones show unmistakable splits and cracks that follow the general pattern of internal organization. The australopithecine innominate bones may show these patterns. Also, the marked thickening in the outer table of the ilium, through the region of the tubercle and pillar, may be detectable in the Swartkrans innominate bone which is broken off across this region; and x-ray would show the thickness of the fossil bones. An examination of the fossils themselves is necessary, however, since casts and pictures fail to reproduce sufficient detail. The present study would have been aided immeasurably by study of the actual fossils.

In spite of this limitation, this paper focuses attention on the importance of a functional analysis and the utilization of a combination of experimental and comparative techniques. Even when there are many more primate fossils, the full story of human evolution will only be elucidated by the use of a wide variety of techniques. Changes in the thickness of bone and in its internal organization offer clues to past behavioral adaptations which are as important as changes in general form.

SUMMARY

1. Benninghoff split-line preparations were done on 4 chimpanzee and 8 human innominate bones.
2. Comparisons of the split-line patterns and areas of thick and thin bone characteristic of man and chimpanzee, demonstrated the relationship of internal structure to behavioral patterns.
3. The relationship of the iliac tubercle and pillar to the balance of a biped was functionally analyzed. The implication of this relationship was drawn for the australopithecine mode of locomotor adaptation.
4. Methods for checking the postulated stage of the fossil adaptation were given.

ACKNOWLEDGMENTS

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PHYSIQUE AND SUCCESS IN MILITARY FLYING [1,2]

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Are there any physical traits associated with success in military flying? If so, what are they; how strong is the association; and what techniques are most likely to disclose the relationship? Answers to these questions have implications beyond the practical utility of any positive findings. They may throw light on the body-behavior relationship, an area of traditional and currently renewed interest in constitutional anthropology.

Critical discussions of this concept, with bibliographies, abound (Sheldon et al., '40; Tucker and Lessa, '40; Tanner, '51; Hunt, '52). It has received recent scientific support, but with many contradictory findings. Difficulties that beset such research are of two main kinds, definition of the problem and methods of analysis. On both sides of the correlation equation, *patterns* of physique and behavior rather than isolated traits should appear. Attempts to correlate head length, for example, with intelligence or introversion are futile. As for methods of analysis, new tools have been devised to supplement an anthropometry oriented toward the study of evolution

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[1] This paper is based in part on a Ph.D. Thesis of the same title, Committee on Human Development, University of Chicago, 1946, available on interlibrary loan or on microfilm from the University of Chicago Library.

[2] The study was in part supported by a Demobilization Award of the Social Science Research Council. I am greatly indebted for aid and counsel to E. A. Hooton, C. C. Seltzer, W. M. Krogman, and R. J. Havighurst; and to my Air Force superiors, O. O. Benson, A. P. Gagge, W. R. Lovelace, II, L. W. Griffis and the late F. E. Randall. Dr. Seltzer has kindly allowed access to unpublished data.

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and race. These include factor analysis, Seltzer's ('46) "disproportions," and Sheldon's ('40) somatotyping. The present study is concerned with a complex but definite pattern of human abilities, military flying, and utilizes classical anthropometry and anthroposcopy, "disproportions," and somatotype in comparing flyers at successive stages of their careers.

Now success in military flying is hardly the *total* personality pattern that Kretschmer or Sheldon would correlate with physique, nor is it a clear-cut psychological concept like intelligence or other primary mental abilities. Its basic ingredients are superb physique and college-level — though not necessarily college-trained — intellect. Flying ability, a complex skill involving physiological as well as mental functions, is the fundamental aptitude involved and is a limiting factor in achievement, as intelligence is in scholastic achievement. But equally important for success in military aviation is the flyer's personality. "Flying is unique in its cumulative anxiety-producing potentialities" (Ford, '45), and "one of the commonest causes for the grounding of pilots or for their inability to learn to fly is a deficient neuro-psychic makeup . . . inability to relax, tenseness, and poor emotional control" (Bauer, '43). Not only is this true for flying in general, but there are some good flyers who are not good military flyers. "Deficiencies in personality and temperament" were factors in 43% of AAF cadet eliminations from training (Flanagan, '42), while the work of Grinker and Spiegel ('45) on psychiatric casualties among Army combat flyers has shown vividly the toughness of character required for success.

Thus, military flying during World War II involved enough of the individual's potentialities, and so deeply, that it can well serve as a type of behavior with which to correlate physique.

Previous studies

Although medical, physiological, psychological, and psychiatric factors in aircrew selection have been widely explored (summarized by McFarland, '53), there are very few studies of morphology. ‘‘Human engineering,’’ or the mechanical integration of flyer and equipment is, of course, not directly relevant. ‘‘Many applicants who pass the physical and mental tests lack flying aptitude, the exact nature of which is unknown. In some cases, not in all, it can be sensed by a skilled flight surgeon. No satisfactory test for it exists as yet’’ (Bauer, ’43). The elaborate AAF psychological testing program emerged with a multiple weighted correlation coefficient, the ‘‘stanine,’’ of + 0.61 between psychological tests and success in training. This is helpful for group rather than individual prediction and indicates the existence of factors in flying success other than those tested. Twenty per cent of cadets so qualified failed in training, while some scoring very low succeeded (Staff psychologists, AAF, ’45).

Quite properly, therefore, there has always been an aura of subjectivity in the selection of aircrew, particularly pilots. At every stage, the flyer’s progress rests not only on his record, but ultimately on the judgment of instructors, superior officers, and flight surgeons. These ‘‘hunches’’ of veteran airmen involve temperament, personality, and physique; and similar standards doubtless prevail in many occupational fields. Do they have any basis in fact?

There are some studies bearing on the problem peripherally. Woods, Brouha, and Seltzer (’43) found, in 632 Harvard ROTC students, a strong positive relationship between physical masculinity and the leadership qualities required for combat officers. One might note that leadership is probably more important for ground and fleet officers than for flyers, and that masculinity correlated not with objective combat performance but with a set of subjective ratings presumed to predict later success.

McFarland et al. (’39) found 200 successful airline pilots to be predominantly of ‘‘pyknic-athletic’’ type, later amended (’53, p. 100) to ‘‘mesomorphic with few bodily disharmonies or disproportions.’’ Their ages ranged from 20 to 47, averaging 32.7 years; height averaged 1763 mm, weight 163.4 pounds. Virtually identical means were reported by Clinton and Thorn ('43) for 21 successful airline pilots, though with a "wide variation in body type, from underweight asthenic to obese." Successful airline pilots were thus on the average taller, heavier, and more stockily built than the general population (table 1) or even selected groups within it — e.g., Hrdlicka's ('25) or Bean's ('31) Old Americans. The same was found true of all civil airline pilots by McCormick ('47). The 7238 license-holders in 1946 averaged 31.6 years in age, 1778 mm in height, and 167.7 pounds in weight.

From the present point of view, the difference between civil and military flying should be kept in mind. Not only are the stresses of airline flight far milder, but some types of combat mission require dash and daring as well as the sound judgment so necessary in transport operations.

Only 4 investigations, none easily available, are at all comparable to the present. (Wilson's ['38] study of Kretschmerian types among U.S.A.A.F. pilots was inconclusive.) Among U. S. Naval aviators studied in 1941, McFarland and Franzen ('44) found 54 instructors, "outstandingly successful flyers," to be even taller (1786 mm) and heavier (168 pounds) than successful airline pilots, though 10 years younger (27.6 years). Some 364–570 cadets in the second stage of flight training were much more mesomorphic ($p < .01$) than college men (tables 2 and 3); and even within this mesomorphic group, there were positive associations between mesomorphy — not alone, but in combination with other components — and graduation, some significant at the 3% level. The authors suggested that the associations might be even stronger in a less highly selected and homogeneous group.

Working with Army flyers, Sheldon ('43a, b) found striking differences in somatotype — chiefly mesomorphy — between 4000 college students and 3000 aviation cadets (tables 2 and 3); between 200 high-ranking graduate flyers and 200 early eliminees from primary training; and between the 50 best and 50 worst of 200 instructors rated by several superiors and colleagues for flying ability under stress. Flyers as a whole were relatively homogeneous, lacking moderate meso-

Stature, weight, and chest circumference

College men and flyers

SERIES	NO.	AGE	STATURE		WEIGHT		CH. CIRC.		CH. CIRC. / STAT.		HEAD CIRC. / CHEST CIRC.	
			M	V	M	V	M	V	M ±	s.e.	M ±	s.e.
			mm		lbs.		mm					
U.S. draft registrants, 1943[1]	99,172	26.0	1739	4.1	152	15.1	908	6.9	52.2			
U. of Minnesota, 1924–1925[2]	1,633	20.1	1745	3.7	143	12.1	885	6.0	50.7			
College men, 1930[3]	23,122	18–20	1744	3.9	142	12.8						
College men, 1927–1940[4]	4,000	18.2	1753		142							
Harvard freshmen, 1939[5]	897	18.2	1770	3.0	150	13.4						
Harvard[6]	480	18.5	1775	3.4	150	11.4	909		51.2			
Harvard, Grant Study[7]	258	19.6	1784	3.3	158	10.5	910	5.5	51.0	.2	63.2	.2
Present study												
Harvard freshmen, 1940	174	18.2	1783	4.3	152	12.8						
U. of Chicago freshmen, 1941	259–119	18.4	1755	3.7	148	13.3	843	7.1	48.1	.3	67.9	.4
Beginning flyers												
AAF cadets, 1943[8]	1,155	21.8	1765	3.4	153	11.2						
AAF cadets, 1942	680	23.2	1760	3.5	153	11.5	923	5.1	52.4	.1	62.0	.1
Graduate flyers, 1944												
Bomber pilots	107		1775	3.1	160	10.2	950	4.9	53.5	.3		
Co-pilots	106		1762	3.1	153	9.7	929	4.9	52.7	.2		
Bombardiers	106		1750	3.7	155	11.3	932	5.7	52.7	.3		
Navigators	100		1752	4.3	151	11.9	934	5.5	53.4	.3		
Photo. recon. officers	150	23.7	1765	3.3	157	11.1						
Fighter pilots	315		1742	3.1	148	10.6	933	4.9	53.6	.2		
Successful combat flyers												
Bomber pilots	80	24.9	1779	3.5	161	9.9	972	4.7	54.7	.3	59.4	.3
Fighter pilots	81–76	24.2	1742	2.6	153	11.1	947	5.3	54.3	.4	60.6	.4

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[1] U.S. Selective Service System, '43.

[2] Jackson ('27).

[3] Diehl ('33).

[4] Sheldon ('40).

[5] Seltzer, unpublished.

[6] Bowles ('32).

[7] Seltzer, in Heath et al. ('45).

[8] Sheldon ('44).

TABLE 2

Somatotype component

SERIES	NO.	ENDOMORPHY		MESOMORPHY		ECTOMORPHY		DYSPLASIA		GYNANDROMORPHY	
		M	S.D.	M	S.D.	M	S.D.	M	S.D.	M	S.D.
College [1]	4,000	3.20	1.19	3.77	1.21	3.53	1.26	3.76	1.46	2.20	0.6
Harvard [2]	1,000	3.20	1.21	3.72	1.24	3.55	1.27	3.71	1.49		
Disease groups [3]	236									2.71 (subgroups 2.40–3.14)	
Flyers											
Naval air cadets [4]	570	3.13	0.92	4.40	0.81	3.20	1.02				
AAF cadets [5]	2,500–3,000	3.28	0.91	4.32	0.79	3.21	1.09			2.17	0.60
Present study											
AAF cadets	680	3.34	1.11	4.18	1.06	2.96	1.13	2.63	0.94	2.50	0.94
Graduate flyers											
Photo. recon. offs.	150	3.13	0.99	4.24	0.95	3.06	1.13	2.37	0.88	2.08	0.88
Successful combat											
Bomber pilots	80	2.68	1.03	4.81	0.92	2.99	1.24	3.38 [6]	1.40	1.63	0.79
Fighter pilots	76	2.94	1.15	4.60	0.79	2.98	1.20	4.14 [6]	1.47	1.76	0.84

[1] Sheldon ('40).

[2] Dupertuis, in Sheldon ('40, p. 78).

[3] Draper, Dupertuis and Caughey ('44).

[4] McFarland and Franzen ('44).

[5] Sheldon ('49, pp. 20, 797).

[6] These dysplasia values, calculated from regional somatotypes, are the only ones comparable to Sheldon's college series. The

on a general estimate, can be compared only within the present study.

TABLE 3

Somatotype group

SERIES	N	ENDOMORPHS			ENDO-MESO	MESOMORPHS			MESO-ECTO	ECTOMORPHS			ENDO-ECTO	BAL	TOTAL %
		Me	Bal	Ec		Bal	Ec	En		En	Bal	Me			
College students[1]	4,000	6	6	3	9	9	13	9	10	4	14	8	5	4	100
Naval air cadets[2]	364	5	2	0	?	18	13	15	?	1	5	10	?	?	100
AAF cadets[3]	3,000	10	2	2	6	26	6	22	4	3	3	14	0	2	100
Present study															
AAF cadets	680	12	5	1	8	18	18	9	10	1	7	6	3	1	99
Photo. recon. officers	150	10	4	2	3	29	10	11	7	1	5	16	2	0	100
Successful combat pilots															
Bomber	80	5	1	0	5	26	8	30	11	0	0	14	0	0	100
Fighter	76	11	0	1	4	24	14	25	5	0	3	13	0	0	100

[1] Sheldon ('40, p. 268–269).

[2] McFarland and Franzen ('44).

[3] Sheldon ('49, p. 797).

penes as well as extremes in all three components. Like Naval air cadets, the AAF cadets included more predominant mesomorphs and massive endo-mesomorphs than college men. Among both groups, trainees and instructors, the better flyers were the more mesomorphic, at the 1% significance level.

But this positive trend in the evidence was abruptly reversed by AAF staff psychologists, who validated against later performance two sets of anthropological and psychological data purporting to predict success in military aviation. No associations whatever were found between ratings made by Draper, Dupertuis, and Caughey ('45) on 503 graduate fighter pilots and the flyers' later training and combat records. Low or insignificant biserial coefficients of correlation were found between Sheldon's ('44) separate measures or combined ratings, including somatotype, and pass-fail in primary flight training for 1155 cadets.

Several possible explanations for these discordant results may be adduced, none wholly convincing. The Draper ratings were based on morphology — anthropometry and somatotype — as well as "internal security" and "personal dynamics" rated in a 5-minute interview. The contribution of physique to the total rating was thus diluted. Validity of the ratings may be questioned when fully 20% of these highly selected and trained graduate fighter pilots were judged "unsuitable for military flying" and over 30% more were "borderline"! Even more important, as pointed out by the original observers and acknowledged by the AAF psychologists who analyzed their data, was the weakness of the success-failure criterion. As applied to combat, the failure category included pilots who were prisoners of war, wounded, missing or killed in action. These are more properly indices of contact with the enemy. "The failure groups may include some men who performed superbly. The efforts made and the results obtained must be given their just weight" (ibid.), as must awards, decorations, and other forms of recognition.

As for Sheldon's study, internal inconsistencies in the data raise doubts as to whether the AAF psychologists' analysis was conducted according to his definitions and methods. For example, one rating, of “physical aptitude,” correlated with pass-fail in primary flight training at or below the 1% significance level. Sheldon defined this rating as combining somatotype and physical performance (’43a); the AAF psychologists restricted it to physical performance alone. It is not clear which rating gave the significant correlation.

In sum, the case for the association of physique with success in military flying is “not proved but not disproved.” It is decidedly worth investigating.

Subjects and measurements

It is hoped that a longitudinal study, following the later careers of flyers measured at the same time, will one day be made. However, the present data, collected under wartime exigencies determining the selection of subjects and measurements (Damon and Randall, ’44), permit only a cross-sectional approach; that is, comparison of essentially the same population at successive stages of its flying career. Standards of selection and performance as well as training conditions remained reasonably constant during the period studied, 1942 to 1945. So did physique, at least over short periods, as shown in the present study by similarity of samples measured months or years apart.

In all, 3675 subjects measured by the writer were utilized: 3193 flyers, 425 college students, and 57 AAF ground soldiers. Several types of data were obtained, the whole battery only for 161 successful combat (“returnee”) pilots: 15 socio-economic items; 7 morphological observations; 26 body, 35 head and face, and 7 tailor’s dimensions; 12 indices derived from these dimensions, including “disproportions”; and somatotype, including dysplasia and gynandromorphy. Regrettably, somatotype photographs could not be taken in any of these surveys. The ratings were therefore anthroposcopic, checked against age and height/$\sqrt[3]{\text{weight}}$ ratio on the spot. Most of the doubtful cases were settled by agreement of two observers, the final decision being the writer’s. Comparison of 680 cadets so somatotyped with 3000 by Sheldon ('49, p. 797) showed, by the X^2 test, no difference in major component dominance (table 3); while averaging the separate components (table 2) resulted in no difference in endomorphy and only slight deficits of 0.10 points in mesomorphy and 0.25 points in ectomorphy for the present series. Inspection thus yielded somatotype ratings not too unlike those based on photographs; and in any case was consistent within the present study. Dysplasia and gynandromorphy, however, should properly be compared only within the present series, due to their lack of standardization.

The Army flyers included 1231 aviation cadets and 109 gunner trainees; 1495 recent graduates (419 bomber officers, 315 fighter pilots, 151 photographic reconnaissance officers, and 610 gunners); and 161 successful combat pilots, 80 bomber and 81 fighter pilots. Except for a slight deficit of some 3% in the relatively tall and heavy Pacific Coast men, the flyers were reasonably representative of all Army flyers in socioeconomic background.

All *beginning flyers* had passed a physical examination far more rigorous than that for soldiers generally — it has been called "probably the severest in the world" (Leedham, '39). Before the War only one out of 4 (Tuttle, '39) and during the War, one out of two (Lyons, '49) self-selected and mostly college-trained applicants could pass it. In addition, the cadets had passed a qualifying test of intelligence and aptitude which eliminated half of the remaining candidates (Flanagan, '42). The cadets comprised several weeks' run, early in 1942, at Kelly Field, Texas, one of three reception centers in the country. They had official limits, sometimes disregarded, on age (18–27 years), height (64–76 inches), and weight (120–200 pounds). Gunners had upper limits of 70 inches and 170 pounds, but no lower limits.

The *graduate flyers* measured in 1944 had survived additional psychological examinations classifying them for type of aircrew duty; a 10-week academic and physical conditioning course; and 45 weeks of flying training. Assignment to specific aircrew duty was based on aptitude, preference, needs of the service (which varied unpredictably), and to a minor extent physique. When they entered as cadets, the minimum weight for pilots had been lowered to 114 pounds, whereas bombardiers and navigators could be 60 inches tall and weigh 105 pounds. All of the flyers studied exceeded these minima.

The 161 *successful combat pilots* were selected from 100 "returnee" fighter and 100 bomber pilots assigned as subjects for aircraft seating experiments in 1945. More rigorous criteria were required than merely a tour of duty overseas, which all had completed. Co-pilots and many pilots with hundreds of hours patrolling against submarines or flying reconnaissance missions in combat areas were discarded. Since some of the pilots had been prisoners of war, an arbitrary minimum of 10 combat missions was set. Most of the flyers far exceeded this figure. The 80 bomber pilots averaged 27 missions and 204 combat flying hours; the 81 fighter pilots, 81 missions and 232 combat flying hours. Without question, these were successful military flyers. Included among them were some fighter "aces," who had destroyed 5 or more enemy planes, and 11 bomber "lead crew" pilots, superb flyers responsible for leading up to 57 planes to a target and back.

Control series. Although the main purpose is to compare flyers *inter se,* such comparison will mean more against a background of the populations from which they were drawn. To show the effect of selection on the dimensions and homogeneity of flyers as compared to civilians and Army ground soldiers, two small and admittedly inadequate series have been included to supplement published studies. Two-thirds of the cadets were college men, for whom few published series contain all the measurements taken here and by the same technique. Accordingly, data are presented for 174 Harvard freshmen measured in 1940 and 119 University of Chicago freshmen (251 for height and weight) measured in 1941. Both were random samples of their classes. While hardly representative of college men nationally, they afford a measure of control for some dimensions.

RESULTS

Socio-economic background. Not only can such data illuminate physical differences which may be found, but some such traits may themselves correlate with success in military flying. The following items did not differ among the different groups and stages of military flying: *basis of induction; country of birth* (U. S. for 98%); *birthplace for U. S. born; birthplace of father and of mother* (80–90% in U. S.); *religion;* and *race* (white, except for 3.7% of cadets with less than half American Indian admixture).

Real differences were found in *national extraction* and possibly in *education.* The principal extraction in all flyers was Old American, with the rest overwhelmingly Northwest European — British, Irish, Germanic, and Scandinavian, in that order. Four per cent were of Slavic and 1% of Mediterranean descent. Successful combat pilots were significantly more Old American in ancestry than cadets, an Old American being a person whose 4 grandparents were born in the United States. Twenty-two per cent of cadets and 60% of the successful combat pilots were Old American on both sides; on one parental side only, an additional 24% and 15%, respectively. This highly significant difference ($p < .01$) is hardly attributable to geographic provenience, since 10% more of the combat pilots than of the cadets were from the East coast, where recent immigrants are most numerous. Old Americans may have tended to become pilots rather than bombardiers or navigators. The greater metrical homogeneity of pilots as compared to the latter groups (tables 1 and 4) lends some support to this hypothesis; but even so, with twice as many pilots in the AAF as bombardiers and navigators combined, pilots should resemble cadets in national extraction more closely than they did. If Old Americans actually were more successful in military flying — still an assumption awaiting confirmation in larger samples — were they eliminated less often from training? Had they "sounder" personalities; or do the physical traits associated with flying success occur

TABLE 4

Graduate flyers; bomber pilots vs. co-pilots

TRAIT	BOMBER PILOTS		CO-PILOTS		BOMBARDIERS		NAVIGATORS		FIGHTER PILOTS		CR/D PILOTS — CO-PILOTS	
	(107)		(106)		(106)		(100)		(315)			
	M	S.D.	M	S.D.	M	S.D.	M	S.D.	M	S.D.	M	V
Weight [1]	160	16.4	153	14.8	155	17.5	151	18.0	148	15.7	+ 3.4	+ 0.6
Stature	1775	54.4	1762	55.3	1750	65.2	1752	75.0	1742	54.8	+ 1.7	— 0.3
Span Akimbo	953	34.1	948	34.8	939	42.1	942	47.4	934	38.7	+ 0.9	— 0.3
Foot												
Foot length	273	10.6	271	10.9	270	12.8	270	11.2	266	10.4	+ 1.4	— 0.3
Foot breadth	102	4.4	101	4.0	102	4.4	101	4.3	100	4.5	+ 2.4	+ 0.8
Instep	199	8.4	197	8.0	196	9.8	199	8.9	196	8.3	+ 1.6	+ 0.4
Ball circum.	256	9.9	252	10.2	256	12.2	255	10.3	253	11.2	+ 3.0	— 0.4
Tailor's dimensions [2]												
Neck circum.	384	14.5	377	15.0	380	16.8	376	17.3	378	15.5	+ 3.5	— 0.5
Sleeve length	818	27.7	816	33.2	811	35.8	814	36.8	812	33.3	+ 0.5	— 1.9
Chest circum.[2]	963	47.5	942	46.3	945	54.1	947	52.1	945	46.2	+ 3.2	— 0.1
Waist circum.	805	49.8	790	45.5	799	51.8	799	46.7	783	45.7	+ 1.4	+ 0.7
Seat circum.	1014	41.9	997	40.6	999	46.5	1009	45.0	996	42.4	+ 3.1	+ 0.2
Leg inseam	831	36.3	822	39.6	820	50.0	813	47.0	823	37.3	+ 1.6	— 1.0
Torso circum.	1669	57.2	1647	50.3	1650	61.0	1640	68.8	1634	56.1	+ 2.9	+ 1.2
Indices												
Height/$\sqrt[3]{\text{weight}}$	12.89	0.46	12.97	0.37	12.87	0.46	12.94	0.45	12.97	0.41	— 1.5	+ 2.3
Chest circum/stat.[2]	53.53	2.83	52.68	2.53	52.70	2.98	53.40	2.90	53.60	2.64	+ 2.3	+ 1.0

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[1] Weight in pounds, dimensions in millimeters.

[2] Tailor's dimensions were taken with cloth tape over light "tropical" wool shirt and trousers, with pockets empty. This added 13 mm to nude chest circumference, as determined by comparing tailor's and nude chest girth (with steel tape) in 200 flying officers. Nude chest girth, as given in table 1, was used for all comparisons and indices.

more often or more strongly among Old Americans? Any one of these possibilities might repay further study.

In *education,* 66% of cadets and 50% of successful combat pilots had attended college or professional school. Alternative explanations come to mind, but after they are weighed, the possibility remains that college men did not do as well as might have been expected. If confirmed on a larger scale, here is another promising research lead.

Civilian occupation and *marital status* differed — successful combat pilots included more students and married men than cadets — but for sampling reasons irrelevant to success in military flying.

Interestingly enough, successful bomber pilots were more likely to be married than fighter pilots (53% vs. 33%) and may have had more civilian occupations involving personal dealings to a high degree (20% vs. 10.5% of salesmen, clerks, proprietors, managers, and officials). Both differences could be expected in view of the divergent personalities of the two groups. For what they may be worth, the impressions of the writer and others who came into close contact with these pilots were of two distinct groups, almost too close to the stereotypes to be true! The fighter pilots were generally carefree and talkative, breezy and informal in speech and dress; energetic painters of the town red; and fairly irresponsible about appointments and other official obligations. The bomber pilots, on the other hand, seemed more like mature men than engaging boys, though averaging only 8 months older than the fighters. As a group they were far more serious, sober, dignified, and reliable.

Morphological observations. These were made according to the Harvard technique of Doctor Hooton. Muscle tonus, graded by feeling the completely relaxed triceps and deltoids, was the only noteworthy difference between cadets and successful combat pilots. Of the cadets, 2.8% had totally relaxed, 37.7% soft, 53.8% medium, and 5.7% had tense muscles; corresponding figures for returnees were 0, 3, 67, and 30%. State of physical training, known to increase muscle tone, cannot account for the difference, since very few of the returnees were exercising regularly. Just what muscle tonus indicates besides physical or physiological fitness — and mesomorphy — is not certain, but it seems to involve a psychic component. One might speculate that combat experience might leave traces on bearing and posture. It would be interesting to test this hypothesis on larger numbers and with more refined physiological measures; and, if such an effect is found, to determine its strength, duration, and physiological mechanism.

Hair color, hair form, eye color, skin color, and vascularity (skin reaction to standardized scratch on chest) did not differ as between cadets and successful combat pilots.

A strong but untested impression of anthropologists was that flyers showed far fewer *surgical scars* than college students.

Anthropometry

Unless otherwise stated, all differences were significant at the 1% level.

Cadets vs. college students. College men were younger, taller, lighter, and had larger chests than national draft registrants (table 1). Aviation cadets, three to 4 years older than college men, were no taller but weighed more and had much larger chests, both absolutely and relative to stature and head circumference (tables 1 and 5). The flyers' body breadths and girths tended also to be larger, but body lengths and head and face dimensions differed little. Cadets had greater sitting height/stature and chest circumference/stature indices and lower height/$\sqrt[3]{\text{weight}}$ and head circumference/chest circumference indices — all mesomorphic traits — and also showed markedly fewer "disproportions" in the last three indices (table 6). Cadets were more mesomorphic, less ectomorphic, and less variable in dimensions, indices, and somatotype (tables 2 and 3).

For a generalized description of group physique, then, indices, "disproportions," and somatotype seem indicated in addition to separate anthropometric traits. Knowing from the basis of selection that cadets were healthier and physically superior to college students, we find this difference best reflected, in the present sample, by the basic dimensions of weight and chest circumference; certain ''disproportion'' indices related to chest circumference and to somatotype; and somatotype itself.

Recent graduate flyers vs. cadets. Tables 1, 4, and 5 show that all graduate flyers exceeded cadets in chest circumference and foot breadth. In chest circumference, 1% significance levels were attained by bomber and fighter pilots, 4–5% levels by bombardiers and navigators, while the co-pilots' excess was not significant. In weight, stature, span akimbo, and foot length, cadets fell between graduate bomber and fighter pilots. Of the two indices available, height/$\sqrt[3]{\text{weight}}$ showed no difference in mean or disproportion percentage; whereas the chest circumference/stature index among the graduates was greater, with fewer disproportions than among cadets. In somatotype component (table 2) the graduates were less endomorphic, dysplastic, and gynandromorphic; there were no differences in somatotype group (table 3). Variability of dimensions, indices, and somatotype was similar in cadets and recent graduates.

Occupational differences among graduate aircrew were even greater than between cadets and graduate flyers in general. Bomber and fighter pilots differed markedly and were less variable than cadets, due largely to the height and weight limits imposed in their assignment. But bombardiers and navigators, so classified primarily on psychological grounds, showed V's consistently and significantly higher than those of bomber pilots, co-pilots, fighter pilots, and often higher than those of the undifferentiated cadets from whom all were drawn!

Graduate flyers vs. successful combat pilots. Recently graduated bomber and fighter pilots were significantly surpassed by their successful combat counterparts only in chest circumference and the chest circumference/stature index. Mean and V showed no or inconsistent differences in the height/

TABLE 5

Aviation cadets vs. college men

RAIT	HARVARD, 1917 (BOWLES, '32: OLD AMERICANS)		HARVARD 1938–1942 (SELTZER: GRANT STUDY)		HARVARD, 1940		UNIV. OF CHICAGO 1941		AAF CADETS 1942		DIFFERENCE: Cadets – College[3]	
NO.	480		258		174		119–259[1]		680–1231[2]			
	M	V	M	V	M	V	M	V	M	V	M	V
	18.5	6.8	19.6	5.2	(18.2)		18.2	6.6	23.2	9.2	+	+
Body dimensions												
ht (lbs)	150	11.4	158	10.5	152	12.8	148	13.3	153	11.5	+	(—)
re (mm)	1775	3.4	1784	3.3	1783	4.3	1755	3.7	1760	3.5	0	0
	1820	3.6					1808	5.2	1808	3.9	0	(—)
g height	921	6.2			926	4.3			927	3.3	0	—
omial			405	4.4	397	4.9	393	4.1	402	4.2	+	0
ac			287	4.9	288	7.2	284	8.1	286	5.3	0	(—)
breadth			291	5.8			283	7.1	288	5.5	(+)	—
depth			201	7.0			204	8.8	206	7.8	+	0
circum.	909		910	5.5			843	7.1	923	5.1	+	(—)
circum.	356	5.8	362	5.8			355	6.3	360	5.9	(+)	0
length	262	4.7							268	4.6	+	0
der-elbow	368	4.6							373	4.6	+	0
breadth	112	5.5							123	5.0	+	—
Head and face dimensions												
circum.			574	2.4			569	2.8	571	2.5	0	0
length	194	4.2			196	3.5	196	3.5	198	3.3	+	0
breadth	150	3.7			153	3.6	155	3.2	154	3.4	0	0
frontal							108	3.8	105	4.4	—	+
ial							105	4.8	106	5.1	0	0
height (MN)					124	5.2	126	5.1	124	5.1	0	0
breadth (BZ)			140	3.5	138	3.3	138	3.6	139	3.5	0	0
face height P)							75	6.9	75	5.2	0	—
height					54	6.4	57	7.6	56	6.6	0	0
breadth					35	6.0	35	6.8	35	6.7	0	0
Indices												
t/$\sqrt[3]{\text{weight}}$			13.0	3.5	13.18	4.3	13.12	4.0	12.90	3.4	—	(—)
ht./stature	51.9				52.01	2.5			52.74	2.2	+	(—)
rd/biac.			72.0	4.8			72.03	6.2	71.52	5.0	0	0
circum/biac.			89.3	6.0			90.59	6.8	89.36	5.9	0	0
pth/biac.			49.8	7.2			51.77	9.3	51.22	8.2	0	0
c/biac.			71.0	4.8	71.8		72.80	7.3	71.24	5.3	—	(—)
circum/ch. um.			63.2	5.2			67.89	6.8	62.04	4.8	—	—
rcum/stature	51.2		51.0	5.8			48.10	7.3	52.44	5.2	+	—
pth/ breadth							71.79	7.4	71.58	7.5	0	0
lic	78				78.05	5.2	79.21	4.6	77.79	4.5	(—)	0
					90.05	5.5	92.36	5.2	88.93	5.8	—	0
					65.86	8.5	62.49	10.9	63.07	9.7	0	0

r weight and the height/$\sqrt[3]{\text{weight}}$ index, N = 242; for stature, N = 259.

r head length and breadth, face and nose height, and nose breadth, cadet N = 1231. For minimum frontal
gonial diameters and upper face height, N = 551.

en cadet value exceeds college, considering the nature of the college series available for comparison as
significance of differences, a plus sign is used; when no difference is evident, a zero; when cadets fall
f college students, a minus sign. Parentheses signify a dubious or slight difference.

$\sqrt[3]{\text{weight}}$ index and all other traits. The two groups did not differ in "disproportion" percentages (table 6) in either height/$\sqrt[3]{\text{weight}}$ or chest circumference/stature indices.

In somatotype component, table 2, the combat pilots were significantly more mesomorphic and less gynandromorphic; in somatotype group, table 3, they showed a significant excess of mesomorphs at the expense of endomorphs and ectomorphs.

Summary. It should be noted that all comparisons to this point involve narrow ranges of flying achievement. This is like comparing freshmen with sophomores or juniors with seniors. Even so, there have been evident a progressive rise in chest circumference, the chest circumference/stature index, and mesomorphy, and a progressive fall in the head circumference/chest circumference index and gynandromorphy from college men to cadets to recent graduates and finally to successful combat pilots. Comparison over a wider range, as in the following section, should disclose more clearly the physical correlates of success in military flying.

Successful combat pilots vs. cadets. Table 7 shows that, as expected, successful bomber pilots significantly exceeded the cadets in all of 25 body dimensions except chest and abdominal depth and trunk height. The level of significance was 1% in 19 traits, 2%, in two, and 5% in one. Bomber pilots were consistently though not always significantly larger in 37 head and face dimensions, chiefly the latter.

Successful fighter pilots were smaller than cadets (at the 1% level) in 8 of 25 body measurements, chiefly stature and its associated body lengths — span, trunk height, shoulder-elbow, buttock-knee. They actually surpassed cadets at the 1% level in chest circumference, chest depth, breadth across elbows, and foot breadth! In face — but not head — dimensions, again unexpectedly, they tended to exceed cadets. This reached the 1% significance level in face length, nose height, several other nasal details, mandible height, chin-neck projection, and neck depth; and the 2% level in interocular diameter and ear implantation.

TABLE 6

Disproportions

SERIES	N	Height	CH. CIRC.	HEAD CIRC.	BI-ILIAC	CH. BREADTH	CH. DEPTH	CALF CIRC.
		$\sqrt[3]{\text{Weight}}$ 13.5–x	Stature x–48	Chest circ. 64–x	Biac. 75–x	Biac. x–70	Biac. x–47	Biac. x–85
		%	%	%	%	%	%	%
Harvard freshmen[1]	300	24.3	44.7	67.3	16.0	60.3	35.7	26.7
Harvard Grant Study[1]	258	14.2	21.3	45.8	16.6	35.2	28.8	24.5
Present study								
Harvard freshmen	174	29.3	...	...	...	...	...	...
U. of Chicago freshmen	119[2]	26.9	58.0	86.4	33.0	33.0	17.8	22.7
Beginning flyers								
Cadets	680	10.0	8.4	25.6	15.4	45.3	21.6	28.1
Gunner trainees	109	11.0	8.3	20.2	12.8	75.9	43.1	30.2
Graduate flyers								
Bomber pilots	107	10.3	4.7	...	...	...	...	...
Co-pilots	106	13.2	6.6	...	...	...	...	...
Bombardiers	106	9.4	7.6	...	...	...	...	...
Navigators	100	11.0	5.0	...	...	...	...	...
Photo. recon. offs.	150	12.6	...	...	...	...	...	...
Fighter pilots	315	10.8	2.2	...	...	...	...	...
Successful combat flyers								
Bomber pilots	80	11.2	0.0	6.2	33.8	31.2	18.8	16.2
Fighter pilots	81–76	12.4	1.3	17.1	23.7	27.6	7.9	22.4

[1] Seltzer ('46).

[2] N = 242 for height/$\sqrt[3]{\text{weight}}$ index, 119 for all others.

TABLE 7

Successful combat pilots vs. aviation cadets

TRAIT	AAF CADETS (680–1231)[1] M	S.D.	SUCCESSFUL COMBAT BOMBER PILOTS (80) M	S.D.	SUCCESSFUL COMBAT FIGHTER PILOTS (76)[2] M	S.D.	C.R. OF DIFFERENCE, PILOTS MINUS CADETS Bomber M	V	Fighter M
Age (yrs.)	23.2	2.1	24.9	2.7	24.2	1.9	+ 5.5	+ 2.0	+ 4.6
Weight (lbs.)	153	17.6	161	16.0	153	17.0	3.7	— 1.8	— 0.1
Stature (mm)	1760	61.6	1779	62.0	1742	44.7	2.6	— 0.1	— 3.2
Span	1808	70.0	1839	70.3	1789	56.3	3.7	— 0.2	— 2.7
Biacromial	402	17.0	407	17.4	398	14.4	2.4	0.1	— 2.2
Bideltoid	458	19.6	467	18.0	457	16.0	4.2	— 1.4	— 0.5
Chest breadth	288	15.8	293	13.9	288	17.9	2.9	— 1.8	0
Chest depth	206	16.1	207	15.7	211	15.7	0.5	— 0.4	2.6
Abdominal depth	216	15.8	217	15.2	215	19.1	0.6	— 0.4	— 0.4
Bi-iliac	286	15.1	297	14.5	287	14.8	6.4	— 1.0	0.6
Foot length	268	12.4	273	10.9	266	10.3	3.8	— 1.9	— 1.5
Foot breadth	98	4.9	101	4.0	101	4.5	6.8	— 3.0	5.8
Chest circum.	923	46.7	972	45.9	947	50.0	9.1	— 0.8	4.0
Calf circum.	360	21.1	366	19.6	359	21.5	2.6	— 1.2	— 0.4
Sitting height	927	30.4	940	30.3	929	27.9	3.6	— 0.2	0.6
Buttock-knee	598	26.9	610	24.6	594	17.9	4.0	— 1.3	— 1.7
Patella height	560	23.8	566	24.9	556	20.0	2.0	0.4	— 1.6
Bi-trochanteric	366	19.0	374	19.6	366	19.8	3.5	0.1	0
Bi-epic. knees	197	11.0	202	12.2	199	11.9	3.4	0.9	1.4
Shoulder-elbow	373	17.4	380	17.0	367	13.6	6.4	— 0.5	— 3.4
Hand length	190	8.3	194	8.2	189	6.2	4.5	— 0.5	— 0.9
Hand breadth	86	4.1	87	3.6	84	3.7	2.8	— 1.9	— 1.8
				Head and face[3]					
Head circum.	571	14.3	576	14.5	572	12.7	3.0	0.1	0.6
Head length	198	6.5	198	6.6	199	5.8	0.7	0.2	1.4
Head breadth	153	5.2	154	5.8	153	5.1	0.9	1.2	— 1.3
Head height	132	5.2	134	5.3	133	5.1	1.9	0	0
Min. frontal	105	4.6	107	4.4	105	4.1	3.7	— 0.9	— 0.4
Bi-tragion	145	4.7	147	5.2	146	5.6	2.2	1.0	1.1
Bizygomatic — bony	139	4.9	141	4.4	139	5.0	2.8	— 1.4	0
— contact	142	4.9	143	4.6	142	5.1	2.0	— 1.1	— 0.6
Bigonial	106	5.4	107	5.0	106	5.6	1.3	— 1.0	0.5
Face ht., M-N	121	6.3	126	5.3	126	5.4	4.6	— 2.5	3.2
Upper face ht.	75	3.9	77	3.5	76	3.5	3.8	— 1.8	1.8
Nose height	56	3.7	58	3.6	57	3.2	4.8	— 1.0	2.9
Nasal root brd.	24	2.2	27	2.3	26	2.3	9.5	— 1.0	4.1
Nasal base brd. (alae)	35	2.4	36	2.3	36	2.4	3.8	— 0.6	1.6
Interocular	32	2.5	33	2.4	33	2.5	2.5	— 0.8	2.8
Ear length	65	3.8	66	4.0	66	4.1	3.1	0.5	1.1
Neck breadth	123	6.1	124	5.6	121	5.0	0.7	— 1.1	— 2.4
Neck depth	110	5.3	124	5.7	122	5.0	8.9	0.4	5.1
				Indices					
Ht. $\sqrt[3]{\text{weight}}$	12.90	0.4	12.90	0.4	12.86	0.5	0	0.3	— 0.7
Sitting ht./stature	52.74	1.2	52.80	1.2	53.26	1.1	0.4	0	4.1
Chest brd./biac.	71.52	3.6	72.10	2.9	72.24	3.8	1.6	— 2.7	1.6
Calf circum./biac.	89.36	5.3	89.80	4.9	89.83	5.8	0.8	— 1.1	0.7
Chest depth/biac.	51.22	4.2	51.06	3.9	52.86	4.1	— 0.3	— 0.9	3.6
Bi-iliac/biac.	71.24	3.8	72.90	3.7	72.12	3.6	3.8	— 0.6	2.0
Head circ./chest circ.	62.04	3.0	59.42	2.7	60.57	3.0	— 8.1	— 0.9	— 4.0
Chest circum./stature	52.44	2.7	54.70	3.0	54.32	3.2	6.6	0.6	5.0
Chest depth/chest brd.	71.58	5.4	70.79	4.9	73.28	5.1	— 1.3	— 0.9	2.9
Cephalic (B/L)	77.79	3.5	77.88	3.8	77.15	3.2	0.2	1.0	— 1.6
Facial (BZ/MN)	88.93	5.2	90.04	4.3	90.42	4.1	2.1	— 2.5	2.7
Nasal (Brd./lgt)	63.07	6.1	62.94	5.8	62.61	5.1	— 0.2	— 0.7	— 0.7

[1] For cadet face dimensions, N = 551, except that N = 1229 for head length; N = 1231 for head brea face height (MN), and nose height; and N = 1224 for nasal base breadth (alae).

[2] For successful combat figher pilots, N = 81 for weight, stature, sitting height, the height/$\sqrt[3]{\text{weight}}$ and ting height/stature indices; N = 64 for bizygomatic — bony; and N = 65 for hand length and breadth.

[3] Four body and 15 facial details, omitted for brevity, appear in the original Ph.D. thesis cited.

The returnees were generally less variable than cadets, but this rarely reached significance.

In mean indices, successful fighter pilots differed more from cadets than did bomber pilots, the former showing 7 out of 12 significant differences (5% level or below), the latter but 4. Clear differences between cadets and both successful combat series occurred in the latter's greater chest circumference/stature and face length/face breadth indices (the long face is possibly an expression of Old Americanism); their unexpectedly higher bi-iliac/biacromial; and their smaller head circumference/chest circumference indices.

Variability of indices, as for dimensions, differed little between cadets and combat pilots, with the latter consistently but (except for facial index) insignificantly less variable.

In 5 of 7 indices (table 6), successful combat pilots showed significantly fewer disproportions (1% level). The exceptions were height/$\sqrt[3]{\text{weight}}$, which did not differ; and bi-iliac/biacromial, where the combat pilots had surprisingly *more* disproportions.

In somatotype component, table 2, both combat pilot groups had significantly less endomorphy and gynandromorphy and more mesomorphy than cadets. Mesomorphy and gynandromorphy tended to be less variable among the combat flyers.

Evidence from somatotype group, table 3, closely parallels that from the separate components, the distributions differing significantly ($p < .01$) by X^2. The combat pilots showed fewer predominant endomorphs, more mesomorphs, and the same percentage of ectomorphs as cadets. Moreover, the combat pilot ectomorphs were almost all secondarily mesomorphs; so that even in this component they were more mesomorphic than cadets.

Recapitulation. Military flyers, a highly selected and relatively homogeneous group both physically and mentally, showed striking and progressive physical differences at progressive levels of training and combat success. These include increased chest circumference, both absolute and relative to stature and to head circumference (table 1); increased mesomorphy; and decreased gynandromorphy. Successful combat flyers also had greater muscle tonus and larger faces than cadets. Marked muscle tonus, large chests without large abdomens, and large faces without large heads are all characteristic of mesomorphy.

PHYSIQUE AND FLYING ABILITY

Comparison of graduate bomber pilots and co-pilots

Of all comparisons in this study, perhaps the most crucial is between bomber pilot and co-pilot graduates of flight training. These men were the end products of a rigorous selective process. As cadets, already a homogeneous group of the physically and mentally elect, they were classified for type of aircrew duty on the basis of aptitude, preference, and needs of the AAF at the time. To qualify for pilot rather than navigator or bombardier training, they needed at least 64 inches in height and 114 pounds in weight; a minimum score on various psycho-physiological aptitude tests; personal approval by a flight surgeon; and agreement by a board of flying officers. They proceeded through preflight academic and physical training (which some failed); then to primary flight training, from which some 65% emerged successful; and then to the second or basic training stage. Eight per cent failed here, the survivors being classified for single- or twin-engine advanced training. The twin-engine men were generally larger, though with many exceptions. The survivors of advanced twin-engine training were assigned, on the basis of their preference, physique, and needs of the service, to bombardment, transport, or twin-engine fighter planes. In general, the twin-engine fighter pilots were somewhat smaller than the others, of whom, in turn, the better pilots were assigned to bombardment rather than transport planes. Within this last bombardment group of highly selected and superior flyers, a further distinction was made into pilot (first pilot, commander) and co-pilot, based on flying ability and somewhat on the personal qualities required for an airplane commander, like leadership, stability, responsibility, and maturity of judgment.

A study of 1218 pilots and 1232 co-pilots by Staff psychologists, AAF ('47), showed good correlation of such designations with earlier scores on pilot aptitude tests.

In comparing physique of bomber pilots and co-pilots, then, two points should be borne in mind.

1. Both groups were selected and trained under the same conditions, during the same period, and were measured at the same time, eliminating sources of error which may be present for the other comparisons. Their ages were not obtained, but there is no reason to believe they differed at all or enough to affect physique. All were in the same state of physical conditioning. Their classification as pilot or co-pilot was based not on physique but on performance. Therefore, any reliable physical differences will be unequivocally associated with success in military flying, in training if not in combat.

2. Co-pilots were able flyers, many of them later becoming first pilots in combat theaters. Since pilots and co-pilots span narrow ranges of physique and flying ability — being the larger and better flyers from the original cadet population and having patterns of aptitudes and personality unlike those of bombardiers, navigators, or fighter pilots — *marked* differences between them can be expected only if physique is closely associated with success in flight training.

Table 4 shows unmistakably that pilots were larger than co-pilots, surpassing the latters' mean in every one of 14 dimensions. Six differences reached significance at the 1% level and another at the 2% level. The significant differences were in weight and its associated girths — neck, chest, seat, torso, and foot — rather than in stature and its correlated lengths. Interestingly enough, waist girth differed relatively little as compared to chest girth, as found above between cadets and successful combat pilots.

The height/$\sqrt[3]{\text{weight}}$ index did not differ, but the pilots' chest circumference/stature index was larger (2% level). Pilots and co-pilots did not differ in disproportions of these indices nor in variability of dimensions or indices; both groups were less variable than cadets in all dimensions.

Discussion. Such signal differences in physique within a remarkably homogeneous group of successful trainees, differing only in degree of excellence in performance and certain personality traits, are noteworthy indeed. The conclusion is inescapable that physique is closely associated with success in flying training, at least for bombardment planes.

Some of the specific differences confirm those found between cadets and the college population and from one level to another of military flying. The larger chest, both absolutely and relative to stature, is the most striking such feature. Others are the larger neck and the absence of a larger waist.

Why should those bomber pilots rated as superior be negligibly taller, but distinctly heavier and stockier than their fellow-trainees? Is physique in this case correlated with flying ability, with the personality traits required for an airplane commander, or both? The last alternative seems most likely. It is common knowledge that, other things being equal, large men inspire more confidence and are more likely to be successful leaders than small men. Gowin ('18) found, as had Galton many years before, that in many occupations, major executives were taller and heavier than minor executives. Sheldon ('43b) concluded that among AAF flying instructors, mesomorphs were strongly preferred and trusted. It would have been interesting to compare the dimensions of his 50 highest and lowest rated subjects if such data had been published. The present pilots and co-pilots were not somatotyped, but increased weight, neck, and chest girths without correspondingly larger waist girths signify that the pilots were more mesomorphic. It may therefore be mesomorphy rather than gross size which distinguishes actual or potential leaders in military aviation.

But pilots were not so rated simply because they were "large" nor because they were leaders. They exceeded co-pilots much less in stature, popularly equated with "size," than in weight. And the two groups were by no means equally competent flyers. Thus, after all possible allowance is made for subjectivity of the training officers' judgments and for the leadership factor, a substantial residue of the physical difference between bomber pilot and co-pilot can be attributed only to differential ability to fly bombardment airplanes. It is a task for future research to determine those factors in flying ability with which physique is primarily associated.

Aerial gunners

The data available (in the original Ph.D. thesis — omitted here for brevity) show aerial gunners to be younger, smaller, and less variable than Army and AAF ground soldiers. They were also more mesomorphic than the latter. Graduate gunners were less gynandromorphic than gunners beginning training, but unofficially relaxed height and weight limits as the War progressed makes it hazardous to compare dimensions in the two groups.

GENERAL CONCLUSIONS AND DISCUSSION

Evidence from bomber pilots and co-pilots and from aerial gunners sustains the findings recapitulated above. The better or more advanced flyers had larger chests, both absolutely and relative to stature, unaccompanied by larger abdomens; more mesomorphy; and less gynandromorphy. Thus, clear evidence of the association between physique and success in military flying has been obtained from all three methods of analyzing physique — classical anthropometry, Seltzer's "disproportions," Sheldon's somatotyping — in all comparisons between flyers and non-flyers and within the flying sample. While the physical differences between cadets and college students might have been anticipated — and in fact closely parallel those between the physically and psychologically selected Grant Study subjects and other Harvard students (Heath, '45; Seltzer, '46) — it is indeed remarkable to find progressive, significant differences in several physical traits within the even more highly selected and homogeneous flying population. The present findings confirm those of Woods, Brouha, and Seltzer ('43) on the relative "masculinity" of promising officer candidates; of McFarland et al. ('39) and of Clinton and Thorn ('43) on the greater weight and stockier build of successful airline pilots than of their civilian counterparts (not so for height, however); and of Seltzer ('46) on the relationship between certain disproportions and personality (personality being a vital aspect of success in military flying). Likewise sustained are Sheldon's main results ('43a, b); namely (1) increased mesomorphy from college men to cadets and from cadets to graduate flyers; and (2) the strong trust and preference accorded to mesomorphs among men of proved flying ability. Sheldon's concept of mesomorphy includes many other positive findings of the present study, such as the increased muscle tonus of successful combat pilots; their greater chest girth without correspondingly increased height, weight, or abdominal girth; and their larger faces without correspondingly larger heads.

How close are the associations between physique and success in military flying? The significant differences between bomber pilots and co-pilots indicate that the correlation must be fairly high. More precisely, the biserial coefficient of correlation based on cadet and successful combat pilot distributions, bomber and fighter combined, between flying success and chest circumference was + .42 ± .04; chest circumference/stature index, + .41 ± .04; head circumference/chest circumference index, — .38 ± .03; mesomorphy, + .29 ± .05; and gynandromorphy, — .47 ± .04. These coefficients and others might contribute to a multiple weighted coefficient comparing favorably with the psychologists' "stanine" coefficient of + .61, while combining physical with psychological criteria might improve the efficiency of aircrew selection. These associations, to reiterate, were within the flyer series. Comparing, over a broader spectrum, successful combat pilots with college men, who comprised 66% of cadets and 50% of the combat pilots — the biserial *r* of success with chest circumference was + .56 ± .05, and with mesomorphy + .36 ± .04. The college series used for these calculations were the select Grant Study subjects, with the largest chests recorded for college men, and Sheldon's ('40) 4000 college students.

Techniques: classical anthropometry. Body measurement, computation of indices, and comparison of central tendency and variability for dimensions and indices proved indispensable for understanding the precise nature and extent of group differences in physique. For example, the progressive increase of chest girth with no increase in stature or abdominal girth, and with very little in weight, isolates one major element contributing to group differences in disproportions and mesomorphy. Again, the progressive reduction in variability with increasingly rigorous selection, as also found in Bowles' ('32) Old Americans at Harvard and in Grant Study subjects (Seltzer, in Heath, '45), heightens the significance of differences found within such a group.

Can exercise account for the chest girth findings? Tanner ('52), discussing his own experimental results and reviewing the literature, concluded that severe physical training could increase chest circumference but little, and then not in all physiques and probably not for many months thereafter. He found somatotype ratings unaffected by the changes produced by severe exercise. The present graduate flyers had had, a year before they were measured, the severe two-month conditioning course which Seltzer ('46a) found to increase average chest circumference in AAF cadets by only 6 mm! When measured, they were exercising mildly, and the successful combat pilots even less. The effect of exercise on chest circumference and somatotype ratings can thus be discounted here.

The same may be said for the effect of age. Weight, closely correlated with chest girth and itself the most sensitive of all traits to ageing in young soldiers (Randall, '49), did not increase in these cadets between 21.8 and 23.2 years of age. Randall found chest circumference to increase about 3.3 mm a year between ages 22 and 25, a negligible amount here. Moreover, successful combat fighter pilots, averaging 24.2 to the cadets' 23.2 years, 18 mm shorter, and no heavier, had larger chests at the 1% significance level!

Many of the measurements of the present study might well be discarded in future constitutional research, chiefly the special ones required for designing gun-turrets, flying clothing, and oxygen masks. Span akimbo, anterior arm reach, squatting diagonal, torso circumference, chin-neck projection, oto basion inferior - subnasale and - supramentale are but a few examples of traits which, though they accord with the evidence from more orthodox measures, contributed so little in this context that they were not worth taking. Even the familiar cephalic, facial, and nasal measurements and indices, as well as traditional qualitative observations, had little value here.

Disproportions. Seltzer's technique ('46; also in Heath, '45, and Hooton, '45) disclosed some of the most striking findings of the present study, even when his critical cut-off points, based on another type of behavior in another population, were employed. To supplement disproportion percentages, it appears useful to compute mean values of the disproportion indices, for, although their trend is generally similar, indicial means may disclose significant relationships not shown by the disproportions. For example, the mean chest circumference/stature index of bomber pilots significantly exceeded that of co-pilots ($p < .02$), though the two groups did not differ in disproportion percentages (tables 1 and 6). The reverse also occurred: successful combat bomber and fighter pilots had significantly fewer disproportions than cadets in the chest breadth/biacromial index ($p < .02$ and $< .01$, respectively), though the mean indices differed insignificantly ($p = .11$).

As Seltzer found for Grant Study subjects, the disproportions correlated unequally with behavior, the familiar bi-iliac/biacromial index being least valuable in both studies. Here, it failed to distinguish college students from the much more mesomorphic and masculine cadets. Indeed, successful bomber pilots, surely among the most mesomorphic and masculine of men, significantly exceeded cadets ($p < .01$) in disproportions! This casts serious doubt on the use of these dimensions alone for a gynandromorphy scale, whether as a ratio or as the discriminant function proposed by Tanner ('51). Bitrochanteric rather than bi-iliac may be the better hip breadth to relate to shoulder breadth, or the shoulder-hip relationship may distinguish among masculine men much worse than between men and women. Both the cadets, with 102 cm, and successful bomber pilots, with 92.4 cm, exceeded Tanner's Oxford men's mean of 90.1 cm on his "3 biacromial minus bi-iliac" scale. In any case, mesomorphs typically have broad hips (Sheldon, '40, p. 39); and, as Tanner ('51) recognizes, "what the rater can so obviously see" as gynandromorphy embodies far more than these or any two measurements.

As for other disproportion indices, chest circumference/stature and head circumference/chest circumference, as Seltzer found, were the most discriminative, chest circumference being the dimension responsible in both cases. The other 4 indices were intermediate, with the chest breadth/biacromial index of less diagnostic value here than in the Grant Study.

Somatotype. Both methods of treating somatotype data, by separate component and by component dominance, primary and secondary, were useful; in fact, they were complementary. The former is the only way to compare dysplasia, gynandromorphy, and the variability of components. The latter, treating physique as a whole instead of piecemeal, reduces 80-odd categories to 15, with three major groupings; affords an excellent shorthand description of group physique; and discloses significant relationships obtainable by no other means. For example, although mean ectomorphy and even the percentage of dominant ectomorphs were similar for cadets and successful combat pilots (table 3), practically all the ectomorphs among the latter were secondarily mesomorphic, whereas cadet ectomorphs were as likely to be secondarily balanced or endomorphic as mesomorphic.

Masculinity and mesomorphy, though often associated, are by no means identical. Sheldon ('49, p. 20) found aviation cadets, much more mesomorphic than college students, negligibly different in gynandromorphy. The present study, rating masculinity somewhat differently, found it to vary with mesomorphy from stage to stage of military aviation, but to different degrees and sometimes out of step. Examples are the different biserial r's; the greater masculinity of graduate flyers than cadets and of graduate gunners than gunner trainees despite similar mesomorphy; and, conversely, the greater mesomorphy of gunner trainees than AAF ground soldiers despite similar gynandromorphy. The writer's unpublished data on civilian truck drivers show a Texas sample to be significantly less mesomorphic but more masculine than a New England — New York sample!

Socio-economic differentiation of successful flyers. Rather unexpectedly, two of the 15 socio-economic background items differed significantly, as they would if associated with success in military flying. It is by no means certain, since data on graduate flyers are wanting and the samples are small, that these traits actually *are* so associated, but they indicate promising leads for further research. The traits are national extraction, with successful combat pilots more Old American than cadets; and education, with the returnees inferior in college training. These differences have already been discussed.

On the whole, the socio-economic backgrounds of flyers at different levels of achievement were so similar, and the possible anthropometric effects of those traits which did differ were so limited, that the observed associations between physique and success in military flying cannot be ascribed to this factor.

Occupational differences among flyers. There is, however, a strong possibility that bomber and fighter pilots, co-pilots, bombardiers, and navigators differed socio-economically as well as physically. Their classification, as noted, was primarily based on aptitude and preference; shifting needs of the AAF were a factor; while physique, in the form of varying and variably applied minimum height and weight standards for all pilots and maxima for fighter pilots, played a minor role in the present samples.

Bomber and fighter pilots differed considerably in dimensions, usually on opposite sides of each cadet mean, though both groups were slightly less variable than cadets. Among successful combat pilots, more bombers than fighters were married and might have had more civilian occupations involving personal dealings to a high degree. They certainly differed temperamentally, as already noted. Bombardiers and navigators were consistently and significantly more variable in physique than fighter pilots, bomber pilots and co-pilots, and in some traits even surpassed the undifferentiated cadets! This last was not the result of selection based on physique. Could it be due to some socio-economic factor like the predominance of Old Americans among pilots and correspondingly greater ethnic and therefore physical diversity among bombardiers and navigators? (For example, Jews were the most highly educated of the three major religions represented among cadets. Did most of them become navigators, for whom advanced education was almost mandatory?). Or do the aptitudes required of bombardiers and navigators appear in a greater variety of physiques than those which characterize pilots?

Suggestions for further research. The present findings should be checked on larger numbers of flyers, by a longitudinal study. If confirmed, a composite multiple correlation or discriminant function, based on the most significant traits, might be devised to aid in aircrew selection. The chest circumference and its relation to stature might even be restored to their hallowed place in military anthropology! (Cf. Davenport and Love, '21).

Specific elements in the observed associations should be isolated. With what factors in flying success is physique associated? With temperament and personality; muscular coordination, strength, speed of reaction; perception; or with all of these? And to what extent with each? The greater size and mesomorphy of pilots as against co-pilots may be a function of the strength needed to handle bomber controls as well as of the confidence which such men inspire. However, Sills ('50) found certain motor skills rather than strength to correlate with mesomorphy. There may actually be a correlation between mesomorphy and visual acuity, as suggested by Grant Study data (Hooton, '45). Aptitude and preference for particular types of aircrew duty may show decided relationships with physique, as other occupational choices have been shown to do (Seltzer, in Heath, '45; Garn and Gertler, '50). All of these problems, which can be readily answered from available data, bear not only on flying ability but also on the larger problem of the relation between man's physique and his behavior.

SUMMARY

A total of 3675 men, measured by one observer, showed marked and progressive physical differences between college students and AAF cadets beginning flight training; and also from stage to stage in military aviation — cadets, recent graduates, and successful combat pilots. All three techniques employed — classical anthropometry and anthroposcopy, Seltzer's "disproportions," and an approximation of Sheldon's somatotyping (inspectional rather than photographic) — gave similar and complementary results.

In general, metrical variability decreased from each of the 4 above groups to the next. Socio-economically, successful combat flyers differed from cadets only in being more Old American in ancestry and possibly less well educated. In qualitative traits, successful combat pilots had significantly greater muscle tonus than cadets.

Chest circumference increased significantly from each of the above groups to the next, not only absolutely but also relative to stature and head circumference. This was not due to exercise nor, among the flyers, to age. Abdominal depth and girth did not increase. Mesomorphy, both in mean strength and in percentage of dominance over endomorphy and ectomorphy, rose and gynandromorphy fell progressively, both

becoming less variable from stage to stage in military aviation. However, mesomorphy and morphological masculinity were independent. Within the rigorously selected and homogeneous Army flyer population, the biserial coefficient of correlation (comparing cadets with successful combat pilots) between success in military flying and chest circumference was + .42 ± .04; chest circumference/stature index, + .41 ± .04; head circumference/chest circumference index, — .38 ± .03; mesomorphy, + .29 ± .05; and gynandromorphy, — .47 ± .04.

A further significant finding was that successful combat pilots had larger faces than cadets, without correspondingly larger heads. This held true even for fighter pilots, who were shorter and generally smaller than cadets. Marked muscle tonus, large chests without large waists, and large faces without correspondingly large heads are all mesomorphic characteristics.

"Disproportions" in certain metrical ratios differed sharply among the groups studied. The head circumference/chest circumference and chest circumference/stature indices were most discriminative, the bi-iliac biacromial least. Hip and shoulder breadth, whether combined as a ratio or as a discriminant function, failed to distinguish the more masculine among these highly masculine flyers.

The above findings were confirmed in comparisons among aerial gunners and in a crucial comparison between recently graduated bomber pilots and co-pilots. Gunner trainees, more mesomorphic and homogeneous than AAF ground soldiers, were themselves more gynandromorphic than graduate gunners. The pilots and co-pilots, chosen to fly bombers because of a specific psycho-physical make-up, were the end products of a rigorous, specialized training course. They differed in flying ability and leadership qualities. The pilots were larger in every one of 14 dimensions, significantly so in 7; these were weight and body girths, chiefly chest, rather than height and body lengths. Waist circumference did not participate in this increase.

Other occupational differences among aircrew which might repay further study were the temperamental contrast between successful bomber and fighter pilots, borne out by marital and civilian occupational statistics; and the significantly increased metrical variability of navigators and bombardiers as compared to pilots and even to undifferentiated cadets.

Since the somatotype concept includes most of the other positive findings, success in military flying can be predicted about as well from height, weight, chest circumference and their ratios, somatotype, and gynandromorphy as from more extensive anthropometry. Further practical and theoretical implications of the present study are discussed.

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THE PERMANENT MANDIBULAR FIRST MOLAR: ITS CALCIFICATION, ERUPTION AND DECAY

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TWO FIGURES

INTRODUCTION

The calcification of the skeleton and teeth is one of the most important aspects of human growth and development. From radiographs, much can be learned about changes with age in calcified tissues, but our present state of knowledge of these events is far from adequate (Noback, '54). Still less well understood is the necrotic breakdown of the teeth, or dental caries. One of the many reasons for carrying out a biographical study of dental growth is to determine whether the grossly measurable rate of calcification of a tooth is related to the timing or severity of its later carious breakdown. Within its limited scope, the present study is an investigation of calcification, eruption and caries in teeth followed for a period of years in a small series of children. Life histories of one class of tooth have been followed: the right permanent mandibular first molar. Various relationships between dental and skeletal growth are discussed: especially the use of the teeth in the assessment of individual growth progress.

Since 1930, a longitudinal or seriatim investigation of child growth has been conducted under the supervision of Dr. Harold C. Stuart at the Harvard School of Public Health (Stuart et al., '39). In this study, the children were all racially White, residents of Greater Boston, and were the progeny of mothers most of whom were clinically healthy during pregnancy. The dental records of these children are now being analyzed from many points of view by different staff members of the Forsyth Dental Infirmary for Children, and the present paper is a part of this collaborative project.

Methods of study

A group of 25 boys and 25 girls were selected at random from the entire series. In most cases, lateral jaw radiographs of the right side of the face were taken at intervals of three months from birth to 18 months, and at intervals of 6 months from 18 months to 10 years of age. At the same time, clinical dental examinations were carried out, and radiographs of the hand taken. These films of the hand have been analyzed by Dr. S. I. Pyle according to the "Red Graph" method of assessing bone age (Pyle et al., '48; Greulich and Pyle, '50).

In beginning the study of dental maturation, the present authors chose the right permanent mandibular first molar. This tooth is relatively advantageous for several reasons. Its calcification is entirely postnatal in most individuals, and its most active development extends over the first 9 years of postnatal life. In addition, radiographs of this tooth are often made in dental practice, especially for the detection of its carious lesions. It has no deciduous precursor which might make the interpretation of its growth more difficult. Finally, this tooth is at or near the center of a typical lateral jaw radiograph. This central position is likely to minimize inaccuracies of angulation of the film which may still further obscure developmental details in the radiographic shadow of a tooth.

A row of outline sketches was made of all the radiographic images of the permanent mandibular first molar for each child. From these sketches, 15 stages of calcification were arbitrarily chosen, as listed and illustrated in figure 1. The stages of completion of the crown are evaluated primarily with reference to its mesiodistal breadth, and those of the roots with reference to the occlusal-apical height of the crown.

In the assessment of these stages in an individual child, his lateral jaw radiograph can be conveniently compared with the standards in figure 1. Among the technical problems encountered in these evaluations are the definitions of some of the more difficult stages. The level of ''crown completed'' is soon followed by ''minimal root formation.'' The latter is defined as the stage at which it is possible radiographically to visualize one or both of the spicules which extend apically from the mesial and distal portions of the completed crown. Later, the cleft between the roots becomes apparent, but this phenomenon should not be regarded as the beginning of root formation, but only the visible divergence of the roots from each other. The interval of 6 months between radiographs of these children made it impossible to find the exact time of onset of cleft calcification. The cleft apparently calcifies and spreads quite rapidly after its first appearance. By the time that the walls of the root canal have converged terminally, the apices of the roots appear mature. Nevertheless, this configuration does not necessarily indicate that the root has ceased to elongate.

The early stages (I–IV) of calcification of the permanent mandibular first molar

Chronological data on the early stages of calcification of the permanent mandibular first molar have been presented by Quintarelli ('32), Campini and Urquijo ('46), Thibault ('40), and especially Kronfeld ('35b).

Histological and radiographic studies indicate that the exact time of onset of cusp calcification is not determinable from a radiograph, since the center is microscopic in size. But by the time a grossly visible mass of cusp tissue has calcified, this minute center can be seen radiographically as an inverted cone (/\ ).

Most investigators agree that both the maxillary and mandibular permanent first molars begin to calcify at, or soon after, birth. Evidence in support of this statement is the occasional occurrence of neonatal lines of disturbed calcification in these teeth. Among the authors who have described these lines are Rushton ('33) and Schour ('36).

Hess, Lewis and Roman ('32) studied radiographs of the jaws of cadavers of newborn infants, and compared their findings on calcification with evidence obtained by "anatomical dissection." They found that the conclusions based on the two methods agree closely. In similar studies by Bustin, Leist and Priesel ('29), and by García ('44), the same agreement was found. We are therefore convinced that the approximate time of onset of dental calcification can be derived with the aid of radiographs.

In the permanent mandibular first molar, several authors agree that the mesiobuccal cusp is the first to calcify (Symington and Rankin, '08; Aoki, '33; Kronfeld, '35b; and Schour and Massler, '41). Evidence from the present study confirms this finding.

In our series of 20 girls for whom adequate radiographs are available within the first three weeks of postnatal life, 4 showed calcification of the mesiobuccal cusp; one at two days, one at 8, and two at 13 days. In such radiographs of 18 boys, none showed calcification of this center within the first three weeks of life. This evidence indicates a slight precocity in the onset of calcification in girls. Such precocity of the newborn female is known to occur in other calcified tissues, particularly in the carpal bones (Hess and Weinstock, '25), and in the calcaneus and cuboid of the foot (Christie, '49; Dunham, Jenss and Christie, '39; Kessler and Scott, '50).

According to Kronfeld ('35b), the degree of calcification at birth may be related to the size and maturation of the entire newborn body. He suggests that one possible method of studying this problem is to record statures and weights of individual children in relation to the amount of dental calcification present.

Of the 4 girls in our series mentioned previously, in whom calcification of the mesiobuccal cusp was observable soon after birth, the lengths and weights are presented in table 1.

In a radiograph published by Symington and Rankin ('08), a calcified mesiobuccal center is also visible in a newborn girl whose length was 44 cm. As is evident from these findings, no apparent relationship was found between early calcification of the mesiobuccal cusp and either length or weight in the early weeks of postnatal life. A more profitable approach to the interpretation of early cusp calcification might be to compare it with the maturation of other calcified tissues in the same individual.

TABLE 1

Crown-heel lengths and weights of newborn girls in whom the mesiobuccal cusp of the permanent mandibular first molar was present in radiographs soon after birth

SERIAL NO.	AGE IN DAYS WHEN MEASURED	CROWN-HEEL LENGTH	WEIGHT	AGE IN DAYS WHEN RADIOGRAPH TAKEN
		cm	*kg*	
10	1	50.5	3.82	13
27	1	51.3	3.86	13
180	8	46.0	2.06 [1]	8
181	3	46.2	2.52	2

[1] This is weight at birth.

Following the appearance of the mesiobuccal center, Aoki ('33) and also Kronfeld ('35b) describe a regular sequence of appearance of three additional centers. These authors state that the interval within which the first 4 centers appear is about two months. In some children, the fifth cusp (hypoconulid or distal cusp) can be seen radiographically, but it is not included in this sequence because of the frequent superimposition of its shadow on those of the adjacent cusps.

The sequence of appearance of centers of ossification in man generally follows a descending order of size. Centers with a large growth potential appear earlier than those whose volumetric contributions to the mature skeleton are smaller (White House Conference, '33). If such a rule occurs in the sequence of first appearance of centers in a multicuspid tooth, large cusps should appear sooner than smaller ones. The relative sizes of the lobes of the permanent mandibular first molar are described by Wheeler ('40, p. 255) as follows:

> "The mesiobuccal lobe is largest by a small margin over either of the two lingual lobes, which are almost equal to each other in size; the distobuccal lobe is smaller than any one of the other three mentioned, and the distal lobe is in most cases much the smallest of all. There is more variance in the development of the distobuccal and distal lobes than in any of the others."

TABLE 2

Order of size and sequence of appearance of cusp centers in the permanent mandibular first molar

USUAL SEQUENCE OF APPEARANCE (AOKI, '33; KRONFELD, '35b)	VARIANT SEQUENCE REVERSAL	DECREASING RELATIVE SIZES OF CUSPS (WHEELER, '40)
Mesiobuccal	Mesiobuccal	Mesiobuccal
Distobuccal	Mesiolingual	Distolingual = mesiolingual
Mesiolingual	Distobuccal	Distobuccal (highly variable)
Distolingual	Distolingual	Distal (highly variable)

Aoki ('33) and Kronfeld ('35b) have described the usual sequence of appearance of the 4 major cusps. This sequence was found in all of the 25 boys in our series, but reversals occurred in 4 of the 25 girls. In table 2, the order of sizes and sequence of appearance of cusps are presented, including the reversals.

Table 2 indicates that variations in the sequence of calcification may chiefly affect the appearance of the distobuccal cusp. This center seems to have the same instability of first appearance as it has in its final size. The large mesiobuccal cusp appears early, as might be expected from its size, but the rest of the sequence does not exactly follow a descending order of size.

In longitudinal growth studies of children or other young primates whose teeth are not liable to decay soon after emergence, radiographic evidence concerning this sequence might be related to the sizes of cusps in the erupted teeth. Although dental casts of some children in our sample were available, the grooves between the cusps of the right permanent mandibular first molar were obscured by occlusal fillings, so that this important relationship could not be investigated.

With the continued growth of the cusps, coalescence occurs, but variations in the angulation of the tooth relative to the film and tube may mislead the observer who attempts to evaluate this process. The peripheries of the cusps fuse earlier than does the central portion of the occlusal surface. In many cases, however, the cusp shadows are superimposed, and convey the impression that the occlusal surface is completely calcified: whereas a radiograph of these teeth with the film in the occlusal plane would show that the surface is still not completely fused centrally.

According to Hess, Lewis and Roman ('32), the cusps of the permanent mandibular first molar fuse at about 9 months, but according to Bustin, Leist and Priesel ('29), this process is completed at 7 months. In an histologic examination of a child aged 6 months, Kronfeld ('35b) found a fusion of the cusps by a very delicate layer of dentine and enamel, but he does not mention which cusps are so connected. At 9 months, Kronfeld ('35b) found that the occlusal surface of the tooth was completely closed. In their chart of dental development, Schour and Massler ('41) showed that at 6 months, the centers of calcification are isolated, but at 9 months, the cusps are fused. According to Churchill ('35), complete coalescence may be expected at 12 months of age.

At the 9 months level, only one boy of the 18 in our series showed a fusion of all centers: while 5 out of 19 girls showed this degree of maturation. Even at 12 months, 6 out of 23 boys had not attained a complete fusion of cusps, but all 20 girls had arrived at this stage. The sequence of fusion of centers showed individual variations, but these differences may in part be artifacts produced by adverse angulations of the radiographs.

Our qualitative data, then, indicate that the initial stages of calcification of the permanent mandibular first molar are usually postnatal, with some precocity of development in females. In the first year of life, however, this precocity is not very conspicuous. A quantitative test of cusp formation was employed in which the mean number of centers present at the age of three months was calculated for 23 boys and 25 girls. The number of cusps calcified was determined rather than the beginning of calcification because the interval between the neonatal and three months radiographs is longer than the time span during which the 4 major cusps typically appear. Without postnatal radiographs taken some two weeks apart, it would be impracticable to define the beginning of calcification on an exact individual basis. The findings in this statistical test are presented in table 3.

TABLE 3

Numbers of centers of calcification observed in the permanent mandibular first molar from radiographs at three months of age

SEX	N	MEAN	S.D.	t	p
Boys	23	2.78	1.59	0.94	0.19
Girls	25	2.40	1.12		

Table 3 indicates that a greater average number of centers was present in the males, but the difference between the sexes is not statistically significant. A slight reversal of calcification rates early in the process of cusp formation is suggested by these findings, but where the sexes are as nearly alike developmentally as they are in this tooth in infancy, this possibility can be proven only by studies of large samples on whom lateral jaw radiographs are available at intervals of about two weeks.

The quantitative chronology of dental calcification

In measuring the rates of dental and osseous calcification, an important consideration is their relationships to chronologic age. In defining the time of onset of calcification of bones in the extremities, Pyle and Sontag ('43) interpolated between the available radiographs of an individual child, and estimated the probable age at which each center began to calcify. This is a sound procedure in dealing with "all or none" phenomena such as the presence or absence of a given center. One calcification has begun, however, this method fails because arbitrary stages of osseous or dental development must be defined within a continuous sequence of events. Instead of trying to decide when a stage of dental development had actually begun, we simply recorded the chronologic age of every child in whom a particular stage could be seen in one of his radiographs. As a result, not every stage was recorded for every child.

TABLE 4

Chronolgy of calcification of the permanent mandibular first molar

STAGE OF CALCIFICATION	BOYS			GIRLS		
	N	Mean age	S.D.	N	Mean age	S.D.
		months			*months*	
Coalescence of at least 2 centers	22	7.0	1.4	22	7.0	1.4
Outline of cusps completed	20	20.7	3.0	18	19.5	2.6
Half of crown completed	17	28.4	4.5	20	25.9	2.8
2/3 of crown completed	14	35.1	4.0	18	32.3	3.0
Crown completed	17	41.5	5.6	21	39.3	4.2
Minimal root formation	16	45.0	4.9	19	42.3	3.7
1/4 of root completed	23	69.1	8.1	24	64.4	4.5
1/3 of root completed	17	74.1	9.2	20	69.0	5.3
1/2 of root completed	21	76.8	8.8	22	74.2	5.4
2/3 of root completed	22	84.3	8.4	18	80.7	5.9
3/4 of root completed	20	90.0	8.1	17	84.7	5.9
Root canal terminally divergent	22	100.4	7.7	16	94.1	8.1
Root canal terminally convergent	13	106.6	7.4	12	102.5	6.0

Table 4 presents the basic findings in this study. For each stage, the standard deviation of chronologic age in months was calculated by the small sample formula (Snedecor, '46).

Sex differences in the emergence and calcification of the permanent teeth

In his paper on the variability in clinical emergence of the first 6 permanent teeth, Hurme ('48) presents mean ages of emergence of all permanent teeth except the third molars. We have generalized the sex differences in these means into a linear equation by the method of least squares (Arkin and Colton, '39). This equation indicates a gradually increasing absolute sex difference in emergence with chronological age, with girls becoming more and more advanced. (For the deciduous teeth, this equation is completely inappropriate.)

Letting y equal the expected age of emergence of any permanent tooth in girls, and x the comparable expected age in boys:

$$y = 0.95\,x.$$

At roughly equivalent developmental stages of the permanent dentition, an average girl is 95% as old as an average boy. This curve also closely approximates the sex difference found in the stages of calcification of the permanent mandibular first molar. Dental development in general is an integrated pattern, so that this conformity in both sexes is not surprising. But the emergence of some classes of permanent teeth fits the curve better than others, and these differences deserve further study.

The velocity of dental calcification and growth

The calcification of a tooth does not occur in isolation, but is intimately related to its eruption and to the growth of its surrounding tissues. The chronology presented in table 4 makes it possible to calculate a few approximate growth rates of the permanent mandibular first molar, and to relate these rates in turn to the growth of some of the adjacent tissues.

In studies of this tooth, Kronfeld ('35b) found that the distance from the mandibular canal to the lowest observable level of the dental organ or tooth changes only slightly from about 1 mm in the neonate to 2 mm at the age of 15 years. Carlson ('44), using tracings from serial cephalometric radiographs of 5 children, related the changes in eruption of this tooth to the inferior border of the mandible. His tracings disclosed two periods of slight decrease in the distance from the apices of the roots to the inferior border of the mandible: one decrease when the roots were partially formed, and the other (in the 3 individuals for whom serial tracings in adolescence were available) was observed after the tooth had come into occlusion.

Although slight changes in the relationships of the apices of the roots to the surrounding structures seem well established, they are of lesser magnitude than other such changes near the crown. In the discussion which follows, the relationships between the roots and their underlying structures are therefore disregarded.

An important difference between the sexes occurs in the occlusal-apical elongation of the tooth, and also in its mature dimensions. Measurements from casts of a group of American children, compiled by Dr. C. F. A. Moorrees, revealed a mean mesiodistal diameter of the crown in males of 11.18 mm, while in females it was 10.74 mm (Garn, '51). The female mean is 96% of the male measurement.

In teeth extracted from skulls of Norwegian Lapps which were sexed by conventional criteria, Selmer-Olsen ('49) discovered that in 123 "males" the mean root length was 14.08 mm, while in 122 "females" this measurement was 13.29 mm. Here the "female" roots averaged 94% as long as those of the "males."

A reasonable estimate of the duration of rapid growth of the tooth can be based on the assumption that calcification begins at one month of age and ends when the walls of the root canals become terminally convergent. This interval in boys on the average is therefore 105.6 months, and in girls 101.5 months. The girls' interval is 96% of that found in boys.

The sex differences in the mature measurements of the tooth and in the duration of its rapid growth are closely similar. These findings indicate that the absolute incremental velocities of calcification in the two sexes are alike, and that the shorter span of rapid dental growth in the female is a simple function of the smaller ultimate size of her tooth.

The velocity of occlusal-apical growth is not constant throughout this span of time. In order to calculate its variations, average occlusal-apical measurements of the tooth were related to average intervals of time between some stages of calcification.

For American Whites, no suitable measurements could be found for the length of the roots in males separated from females. Instead, pooled means from Black ('02) were used. From his average of 13.2 mm for root length, the amount of growth from the stage of "crown completed" to that of "$\frac{1}{4}$ of the root completed" equals $\frac{1}{4}$ of 13.2 mm, or 3.3 mm. Similar calculations were made for the occlusal-apical increments between several of the other stages.

Since Black's measurements were based on a pooled sample of teeth from both sexes, mean intervals between stages of calcification were computed for boys and girls combined.

From these data, it was possible to plot occlusal-apical height of the tooth as a function of age. The resulting curve could only be fitted to a complex polynomial equation. Rather than deriving such an equation, and differentiating it to arrive at elegant instantaneous growth rates for the tooth at different stages, the much simpler expedient was used of assuming a constant, linear growth rate between stages. For each interval between stages, the growth rate is expressed as micra per day. All of these rates are presented in table 5.

This table indicates that the initial occlusal-apical elongation of the crown is slow, as recognized by Carlson ('44) from radiographs, as well as by Kronfeld ('35a) from histological sections. Schour and Massler ('40), and Massler and Schour ('46) found that in this tooth, enamel deposition of the cusps occurs at about 4.5 μ per day. The dentine of the gingival third of the crown is deposited at about 3.0 μ per day, that of the middle third at 3.5 μ, and "at the growth center" at about 4.5 μ per day.

These findings are of the same order of magnitude as our estimates, and suggest that much of the acceleration in the terminal growth of the crown occurs in the dentine.

At the end of this phase of rapid growth of the crown, its outline is completed. Then a period of slower calcification occurs while the roots are beginning to develop, and the only rapid calcification visible at this stage is the apical expansion of the cleft between the roots.

TABLE 5

Calculated mean velocities of occlusal-apical elongation of the permanent mandibular first molar (both sexes pooled)

INTERVAL BETWEEN STAGES	MEAN AMOUNT OF OCCLUSAL-APICAL GROWTH	INTERVAL OF TIME BETWEEN STAGES	LINEAR GROWTH RATE
	mm	*months*	*μ/day*
Entire calcification of tooth	21.0	103.5	6.8
Onset of calcification to completion of cusps	2.6	19.1	4.5
Completion of cusps to 2/3 crown	2.6	13.6	6.4
2/3 crown to crown completed	2.6	6.7	12.9
Crown completed to 1/4 root	3.3	26.3	4.2
1/4 root to 1/3 root	1.1	4.8	7.6
1/3 root to 1/2 root	2.2	4.0	18.3
1/2 root to 3/4 root	3.3	11.8	9.3
3/4 root to convergence of root canal walls	3.3	17.2	6.4
Subsequent growth	Slight	Unknown	Very slight

Once the roots have attained about $\frac{1}{3}$ of their "completed" elongation, they enter a growth spurt which accounts for a considerable proportion of their total increase in length. Finally, the roots grow more and more slowly for an unknown span of years.

In an attempt to relate the preceding events to the pattern of eruption, a stage was defined radiographically as "alveolar emergence." At this stage, the tips of one or more cusps are at or just above the superior margin of the alveolar process. The interrelationships between stages of calcification and emergence are shown in table 6.

In this table, data on the average age of clinical emergence have been calculated from the means of Hurme ('48) for White boys and girls of Northwestern European origin. Hurme's unpublished researches on the Boston children from whom the 50 members of our study were drawn indicates that these norms are quite suitable for the purposes of this paper.

These data on clinical emergence, together with the calculations in table 5, show that the tooth elongates slowly when it has not yet emerged from the alveolus. Immediately prior to alveolar emergence, the only rapid calcification occurs at the cleft between the roots. This growth at the cleft coincides with two additional events in the pattern of eruption. One is the rapid resorption of bone surrounding the crown. The other event is apparently the change in the tilting of the tooth. Initially, the occlusal plane slopes downward mesially and lingually. With eruption, it becomes more nearly horizontal.

TABLE 6

Relationships of calcification, eruption and emergence

STAGE	BOYS		GIRLS	
	Mean age	S.D.	Mean age	S.D.
	months		*months*	
Crown completed	41.5	5.6	39.3	4.2
Minimal root formation	45.0	4.9	42.3	3.7
Alveolar emergence	64.6	8.0	61.2	7.7
1/4 of root completed	69.1	8.1	64.4	4.5
1/3 of root completed	74.1	9.2	69.0	5.3
Clinical emergence (Hurme, '48)	74.5	9.6	71.3	9.6
1/2 of root completed	76.8	8.8	74.2	5.4

In the interval from alveolar to clinical emergence, the elongation of the tooth is still only moderately rapid. This finding contradicts the opinion of Schour ('48) that the speed of dental development is "most active and intense before eruption." Our evidence indicates, on the contrary, that calcification is most rapid soon after clinical emergence, rather than just prior to it. After occlusion is attained, the roots elongate at a much slower rate, and continue to grow very slowly for years afterward.

From serial dental casts, Dr. See Siong Tan and Mrs. Vilma R. Hunt have measured the eruption of some of the permanent teeth in a large group of children. These measurements of the right permanent mandibular first molar were available for three members of the present sample, and were therefore analyzed to ascertain the relationships between the occlusal-apical elongation of the entire tooth and the amount of occlusal-gingival eruption. This analysis provided information concerning the eruption of the tooth as it relates to the accompanying growth of the periodontal tissues. The findings in these cases are presented in table 7.

TABLE 7

Increments of calcification and eruption of the permanent mandibular first molar

STAGE	AGE INTERVAL	ESTIMATED AMOUNT OF ROOT ELONGATION	AMOUNT OF OCCLUSAL-GINGIVAL INCREASE
	years	*mm*	*mm*
Case 74 (female)			
1/2 root to 3/4 root	7–8	3.3	1.4
3/4 root to ''completion''	8–9½	3.3	0.2
Case 149 (female)			
3/4 root to ''completion''	6½–8	3.3	0.9
Subsequent growth	8–16½	?	2.1
Case 65 (male)			
1/2 root to 3/4 root	7½–9	3.3	0.9
Subsequent growth	9–13	3.3	0.8

In the interval from about ''$\frac{3}{4}$ of the root completed'' to the termination of its rapid growth, the root elongates considerably more than the increase in the occlusal-gingival height of the crown, as shown in table 7. Carlson ('44), using serial cephalometric radiographs, found that at this time the root probably grows down into the underlying bone, and our data might also be explained on this basis.

So far, however, no satisfactory measurements have been made of the rates of appositional growth of the alveolar process, relative to some supposedly fixed reference level such as the mandibular canal. As Brodie ('48) points out, the growth of the alveolar process is postnatal. During the calcification of the crown, the alveolar process grows in the direction of the occlusal plane much more rapidly than does the tooth itself.

Once the root canals become fully convergent toward their apices, the subsequent elongation of the roots is protracted but slight. Along with this slight growth of the roots, the gingival-occlusal height may also increase slightly in some individuals, but whether this later increase equals the amount of terminal growth of the roots is unknown. As suggested by Kronfeld ('35b), other intervening complications may include tilting or drifting of the tooth and gingival recession. Until more is known of changes with age in the alveolar process and periodontal tissues, no description of calcification or eruption will be complete.

Although the relationships between calcification and eruption appear reasonable in terms of averages, individual variations in these events are equally important. In table 8 is presented a distribution of the degrees of root formation which were found at the time of alveolar emergence, and also when the tooth was first clinically observed in the mouth.

The interval of 6 months between radiographs and clinical examinations of the oral cavity does not permit a precise determination of the time of clinical emergence. Since the same interval applies to alveolar emergence, the comparisons in this table are actually quite meaningful. It is evident that the variability in root development is moderate at the time of alveolar emergence, but far greater at the time when the tooth was first seen in the oral cavity. As shown previously, since the elongation of the root in the occlusal-apical direction is much less rapid at alveolar emergence than it is at or soon after clinical emergence, this finding is entirely understandable.

According to Saito ('36), who studied root development in Japanese children, 96% of a group ranging from 7 to 8 years of age (84–96 months) had erupted the permanent mandibular first molar. Of the individuals with this tooth present in the oral cavity, 20% had two-thirds of the root completed. In another sample aged 8 to 9 years (96–108 months), 89% had "completed" root formation, and between 9 and 10 years (108–120 months), all had attained this stage. These findings resemble ours closely.

TABLE 8

Degree of root formation at the time of alveolar emergence and first recorded appearance of tooth in oral cavity

ROOT STAGE	ALVEOLAR EMERGENCE		FIRST PRESENCE NOTED IN ORAL CAVITY	
	No. boys	No. girls	No. boys	No. girls
Total series	21	21	21	17
Beginning of root to 1/4 complete	10	8	0	1
1/4 complete	7	10	5	1
1/4 to 1/3 complete	0	0	1	1
1/3 complete	3	3	2	4
1/3 to 1/2 complete	0	0	0	1
1/2 complete	1	0	9	6
1/2 to 2/3 complete	0	0	1	0
2/3 complete	0	0	2	0
3/4 complete	0	0	0	3
3/4 to almost complete	0	0	1	0

Table 8 also indicates that the calcification of the tooth and the growth of the alveolus and periodontal tissues are not identically synchronized in all individuals, and this finding substantiates the conclusions of Brauer and Bahador ('42). *These variations suggest that on an individual basis, the calcification of a tooth may be a more meaningful indication of somatic maturation than is its clinical emergence.* A further advantage of studying calcification is that it can be assessed at any time during the span of active growth of the tooth: whereas clinical emergence is a fleeting event whose exact time of occurrence is often impossible to determine.

If the average stage of root development which corresponds to the time of clinical emergence could be found for most or all of the teeth, and were equivalent in different human populations, it might be possible to compute norms of clinical emergence for any human group from a sufficiently large sample of dental radiographs of children of known ages. For permanent mandibular first molar, this equivalent stage is intermediate between the attainment of one-third and one-half of the completion of the root.

Sex, calcification and caries

In the preceding portions of this paper, some of the constructive phases in the life of a tooth were considered: especially the accretion of its mineralized components. Yet in many children, destructive necrosis or caries appears in the permanent mandibular first molar soon after it emerges into the oral cavity.

Mellanby ('27) and Hurme ('43) have suggested that the more rapidly the enamel of a tooth forms, the more rapidly it will decay later. In the permanent dentition, the first mandibular molar is the tooth which undergoes the fastest amelogenesis (Kronfeld, '35a). Hurme ('43) and Finn ('52) have further postulated that the earlier onset of carious lesions in the permanent teeth of girls may also be related to their briefer span of development and earlier clinical emergence.

Under Hurme's supervision, complete histories of carious breakdown for each deciduous and permanent tooth have been charted at the Forsyth Dental Infirmary for Children for the members of the present series. With his kind permission, his data for the right permanent mandibular first molar are used here. From this information, the ages were determined, wherever possible, at which occlusal and proximal carious lesions were first observed in this tooth. These two sites were chosen to represent both of the chief classes of carious lesions in young individuals (Bodecker, '52): pit and groove lesions (occlusally) and smooth surface lesions in proximal sites.

In individual teeth for which the time of the first detection of any necrotic lesion could be determined within an interval of one year, this event was correlated with the previous growth pattern of the tooth. But occasionally, when the interval between two clinical dental examinations was more than one year, and the lesion was found at the second examination, such a child's calcification and caries were not correlated further. This process of exclusion unfortunately reduced the numbers of the children studied, so that future analyses of larger samples of children would be very desirable. In table 9 are presented the mean ages at which the first occlusal and proximal lesions were found in boys and girls. But since radiographic shadows of calcifying teeth do not permit an unambiguous separation of growth rates for enamel, dentine and cementum, it is not possible to relate the present findings to the specific growth spans of any one of these tissues. Instead, the timing of detectable carious involvement is related to the calcification of the whole tooth. If the age of first clinical detection of a lesion were related only to the spans of calcification in the two sexes, one could readily obtain the expected age of detection of a lesion for girls by substituting the boys' mean age in the equation calculated earlier for the sex difference in the emergence of

TABLE 9

Mean ages of detection of carious lesions in the permanent mandibular first molar of boys and girls

SITE	BOYS			GIRLS			SEX DIFFERENCE
	Age of detection (mos.)			Age of detection (mos.)			
	N	Mean	S.D.	N	Mean	S.D.	
Occlusal	22	86.2	10.1	17	79.8	8.1	6.4
Proximal	13	145.3	8.8	12	119.9	10.3	25.4

the permanent teeth and calcification of the permanent mandibular first molar: Y = 0.95 X. For occlusal lesions, this expected age in girls would be 81.9 months, which is 95% of the observed mean age in boys (86.2 months). The expected sex difference is therefore 4.3 months. Although the actual sex difference in occlusal lesions is 6.4 months, these lesions appear so soon after clinical emergence in most Boston children that their onset in both sexes does not diverge markedly from the hypothesis of Mellanby and Hurme.

The proximal lesions, however, show a considerably earlier average age of first detection in girls than can be explained from the timing of calcification or emergence alone. Where necrosis tends to occur some years after clinical emergence at a "smooth surface" site, what Finn ('52) calls "some heretofore unexplained difference" between the sexes in dental decay seems to be operative. This unknown mechanism may predispose girls to an earlier detectable onset of caries than is true of boys — particularly at smooth contact points.

The assessment of individual dental maturation

In table 4, the statistical data on the chronology of calcification of the permanent mandibular first molar make it possible to construct a simple graph for each sex on which the development of this tooth can be recorded for an individual child. This graph is set up on the same axes as the "Red Graph" of osseous maturation of the hand, as described by Pyle et al. ('48), and by Greulich and Pyle ('50), so that skeletal and dental development can be easily compared. Alveolar emergence, presence in the oral cavity, and occlusal or proximal necrotic breakdown can be added to the line of dental maturation if desired.

In such a graph, the horizontal (x) axis represents chronological age, and the vertical (y) axis indicates skeletal or dental age. A series of 13 of our 16 stages of development of the permanent mandibular first molar are located on the graph as horizontal lines parallel to the x-axis, but at distances upward from this axis corresponding to the means for the dental stages on the vertical axis. In addition, a diagonal line extends from the origin of coordinates, bisecting the angle between the two axes. This diagonal indicates a pattern in which chronological age is equal to osseous or dental age.

For an individual child, when a stage of dental calcification is known at any chronological age, a dot is plotted on the horizontal line corresponding to the dental stage. The x-coordinate of the dot corresponds to the chronological age of the child. When several radiographs of the permanent mandibular first molar of this child are available, a sequence of dots is recorded and connected by a line. This line represents the individual chronology of calcification of this tooth. The other important events in the history of the tooth are then conveniently recorded as desired. Figure 2 shows such graphs for a boy and a girl.

Growth arrests in teeth and bones

Microscopic evidence of arrested growth in the teeth have long been recognized, but whether these features are normal or pathological is not always certain. The lines of Retzius in the enamel and of Owen in the dentine, neonatal lines in dentine and enamel, and interglobular spaces in the dentine are such traces observable histologically in human teeth. Among the many students of these features of teeth are Mellanby ('22), Rushton ('33), Massler, Schour and Poncher ('41), and Schour and Poncher ('37).

In the skeleton, lines of arrested growth are frequently observed both in osseous remains and in radiographs, and in extreme cases are unquestionably pathological (Harris, '28). Neonatal lines of arrest are also known in the bones of the foot of infants at the age of one month (Sontag and Harris, '38). An important potential use of a developmental graph such as the preceding one might be the diagnosis of growth disorders in children from dental radiographs.

We have traced the pattern of calcification of the permanent mandibular first molar on ‘‘Red Graphs’’ which were prepared by Dr. S. I. Pyle on the children of our series, and will present these findings in more detail in a later paper.

The characteristic finding in tracing ‘‘bone age’’ and ‘‘dental age’’ serially on the same child is that severe and prolonged delays in osseous maturation, as shown when the ‘‘least mature centers’’ fail to progress in their calcification in the hand, can also be seen in the tooth, as shown in figure 2. In general, however, the delays in dental calcification are less prolonged than those of the wrist and hand. This technique deserves further investigation, since it apparently puts into the dentist’s hands a valuable aid to the assessment of growth progress in individual children.

Dental calcification, eruption and phylogeny

Dental calcification is of importance to the evolutionist as well as to the student of human physical growth. As discussed previously, in the permanent mandibular first molar, the distobuccal (hypoconid) cusp seems to be relatively unstable both in the timing of its first appearance and in its ultimate size.

This cusp is relatively variable in size in all three permanent mandibular molars — particularly the second and third. The phylogenetic pattern of molar reduction in man — particularly the transition from the Y to the plus pattern of the grooves in these teeth — is largely mediated by the relative shrinkage of this cusp (Gregory, ’22). This region of the mandibular molars, as well as the adjacent distal (hypoconulid) cusp, are apparently unstable in both ontogeny and phylogeny.

In our present series of Boston children, the cleft between the roots of the permanent mandibular first molar begins to calcify soon after the first appearance of mesial and distal spicules of the newly-forming roots. At this time, the tooth is beginning its movements of eruption. Indeed, the rapid development of the cleft might lead one to suspect that it acts as a wedge in propelling the tooth during eruption.

On the other hand, the cleft does not calcify at the onset of eruptive movements in all human molars. A conspicuous delay in this calcification occurs in taurodontism, in which a large pulp chamber occurs in combination with short, partly fused roots (Keith, '32).

In the mandible of an early adolescent Neandertal specimen from Krapina, Croatia, radiographic evidence indicates that the second permanent molar is in occlusion, but the root canal walls are still terminally divergent. The cleft, however, is only incipient (Gorjanović-Kramberger, '06; Keith, '32).

Taurodontism is clearly the outcome of an unusual developmental pattern, by comparison with the calcification of most other primate molars (Senyürek, '39). In a child, if a strongly taurodont permanent mandibular first molar developed according to the chronology presented in this paper, the cleft might begin to calcify some 4 years later than that of an average child in our series.

Since the formation of the cleft in taurodont molars occurs at the end of eruption rather than at its onset, in these teeth the calcifying cleft cannot possibly initiate the movements of eruption. Its role in the eruption of other molars, however, is unknown.

DISCUSSION AND SUMMARY

A serial or longitudinal study of the calcification, eruption and decay of the right permanent mandibular first molar has been completed as a part of an investigation of child growth at the Forsyth Dental Infirmary for Children and the Harvard School of Public Health. Radiographic images of this tooth were arbitrarily divided into 15 stages of calcification. For each sex, the ages at which each stage occurred are presented as means and standard deviations. A total of 25 boys and 25 girls, racially White and residents of Greater Boston, were included in the present series.

Lateral jaw radiographs such as those used in this study apparently provide a good approximation of the time of onset of calcification. A precocious onset of this stage is not correlated with crown-heel length or body weight at birth. A few girls showed this early onset, but none of the boys. At three months of age, however, an insignificantly greater average number of calcified cusp centers occurred in the boys.

The onset of coalescence of the cusp centers on the average is visible at 7 months in both sexes. At later stages of calcification, however, a slight linear increase in the precocity of female development was observed. The average span of active growth of this tooth in females is 96% of the male span, and the female tooth is also smaller by an equivalent amount in its linear dimensions. The absolute velocities of elongation of this tooth in the two sexes are therefore similar.

The growth in height of the crown accelerates until this structure is completed. The initial elongation of the roots is slow, but between the stages when one-third to one-half of the roots are calcified, their growth is rapid. Later, root growth decelerates for an unknown period of years.

When the preceding rates of elongation are related to eruption, it is found that the initial slow growth of the roots coincides with the tilting of the occlusal-apical axis of the tooth toward its mature vertical inclination. Root growth is only slightly more rapid during the interval from alveolar emergence to clinical emergence. From clinical emergence until the tooth approaches the occlusal plane, the speed of elongation of the roots is maximal. The final one-quarter of root growths is slower, but this elongation is greater than the occlusal-gingival eruption of the tooth as measured from casts. This difference may reflect downward growth of the roots toward the mandibular canal, upward growth of the periodontal tissues, or more likely, both patterns.

Variability in root development is moderate at the time of alveolar emergence but far greater at the time when the tooth is first clinically observed in the oral cavity. Calcification and eruption are not identically synchronized in all children, but on the average, clinical emergence occurs soon after one-third of the root is completed.

If this average relationship is constant in human populations, and if corresponding relationships between calcification and clinical emergence become known in other classes of teeth, it would be relatively easy to calculate norms for clinical emergence from dental radiographs.

On an individual basis, the calcification of a tooth may be a more meaningful indication of somatic maturation than is its clinical emergence. Another important advantage of calcification is that it can be evaluated at any time during the span of active growth of the tooth. Clinical emergence, however, is a fleeting event whose timing cannot invariably be recorded for an individual child.

Some authors suspect that the speed of dental calcification and the timing of clinical emergence may be related to the time of onset of carious lesions. In Boston children, occlusal lesions appear so soon after the time of emergence that in our series, the sex difference in the mean age of detection of the first occlusal lesion closely resembles the contemporaneous sex differences in calcification and emergence. But proximal lesions show a precocity of first detection in girls which is far greater than the development precocity of the female tooth. The biochemical mechanism underlying this vulnerability of proximal sites in girls is unknown.

Comparisons between dental and osseous calcification in the same child can be made by tracing the ages at which the various stages of dental calcification occur as an additional line on a "Red Graph" of osseous maturation of the hand. Such individual graphs show that developmental arrests in bone growth often coincide with arrests in the tooth. In general, however, delays in dental calcification are less severe or prolonged than are those of the wrist or hand. Since delays in calcification affect both the bones and teeth, it is possible to use dental radiographs for the assessment of growth progress in children.

In all three permanent mandibular molars, the distobuccal (hypoconid) and distal (hypoconulid) cusp are relatively variable in size. These cusps are especially important in the mechanics of molar reduction in man. The ontogenetic and phylogenetic instability of these lobes in the molar crown may prove to be interrelated.

The rapid growth of the cleft between the roots in most human molars occurs at the onset of the movements of eruption. Perhaps the growing cleft acts as a wedge in moving the tooth. Yet in taurodont molars, the cleft appears much later, when the tooth is virtually in occlusion, so that in these teeth, at least, the cleft cannot serve such a mechanical function.

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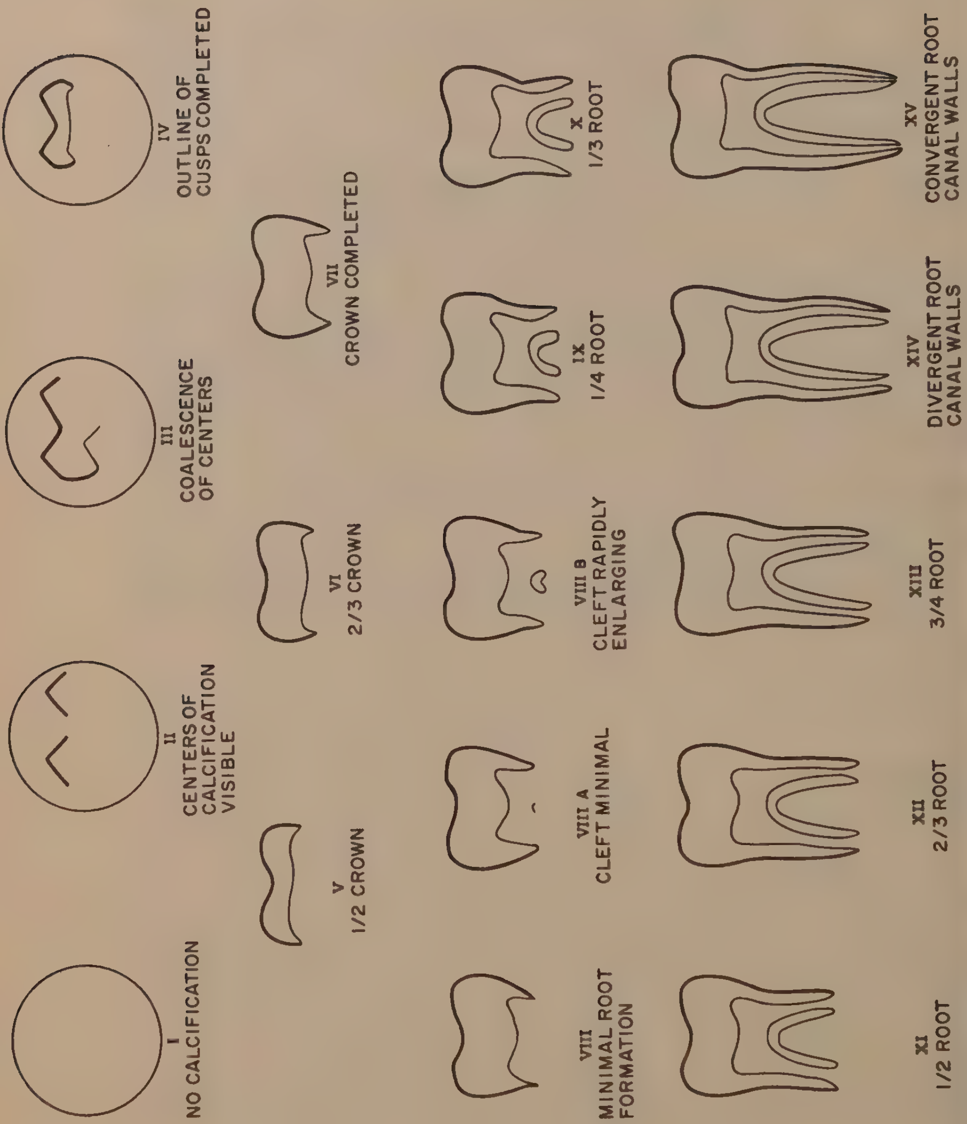
I
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II
CENTERS OF
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VISIBLE
III
COALESCENCE
OF CENTERS
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OUTLINE OF
CUSPS COMPLETED
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1/2 CROWN
VI
2/3 CROWN
VII
CROWN COMPLETED
VIII
MINIMAL ROOT
FORMATION
VIII A
CLEFT MINIMAL
VIII B
CLEFT RAPIDLY
ENLARGING
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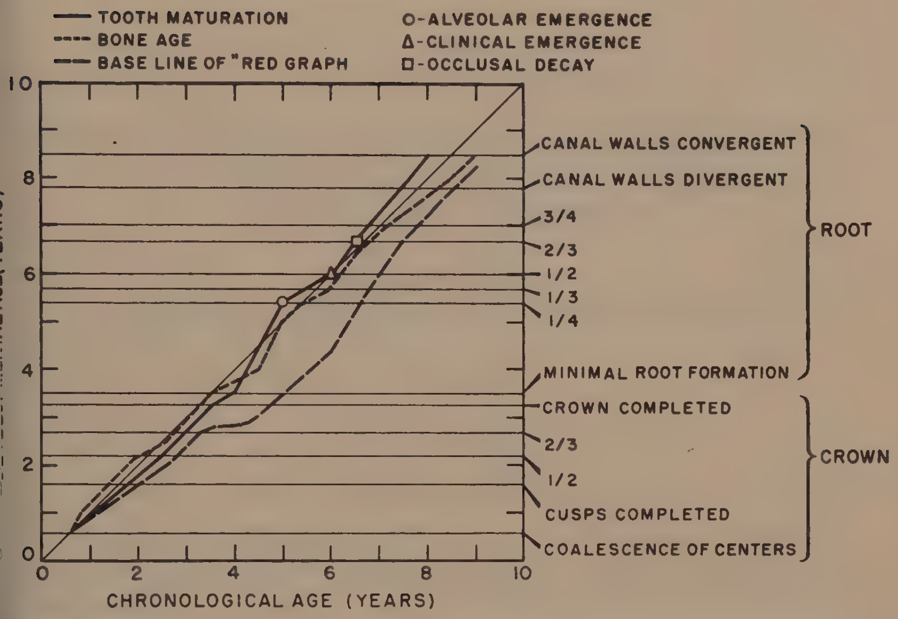
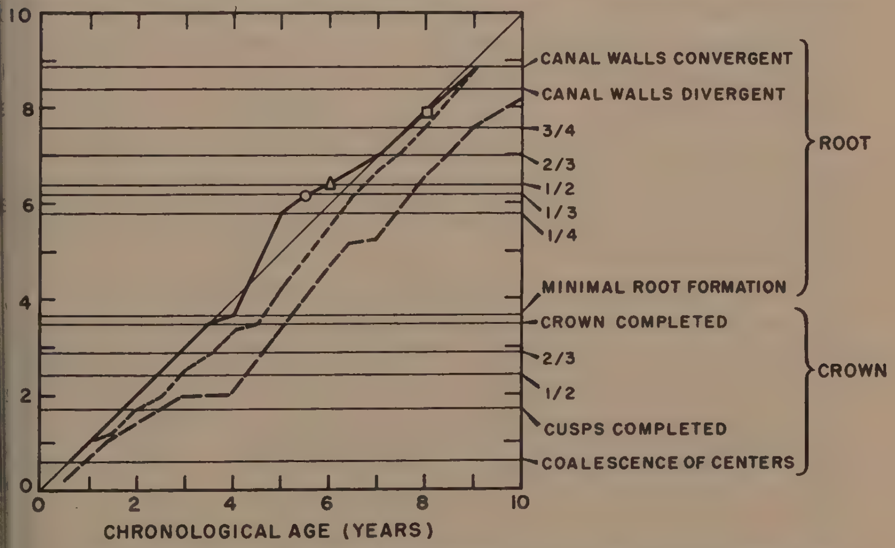


NDIVIDUAL GRAPH OF FEMALE OSSEOUS AND DENTAL MATURATION



DIVIDUAL GRAPH OF MALE OSSEOUS AND DENTAL MATURATION

Figure 2

THE SPHENO-ETHMOIDAL ARTICULATION IN THE ANTERIOR CRANIAL FOSSA OF THE AUSTRALIAN ABORIGINE

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FOUR FIGURES

INTRODUCTION

Topographical considerations

The spheno-ethmoidal articulation in the anterior cranial fossa of the skull is variously described in the standard textbooks.

Thus Gray ('49, p. 277) "Posteriorly the cribriform plate (of the ethmoid) articulates with the anterior part of the body of the sphenoid at the spheno-ethmoidal suture." No mention is made of the ethmoidal spine of the sphenoid in the text but it is illustrated and labeled (figs. 316 and 334). Cunningham ('51, p. 225) "Jugum sphenoidale . . . terminates anteriorly in a ragged edge that articulates with the cribriform plates of the ethmoid." Ethmoidal spine of the sphenoid is neither mentioned nor illustrated. Buchanan ('49, p. 177) "The anterior border of the jugum is projected in the middle line into the ethmoidal spine, which articulates with the posterior margin of the cribriform plate of the ethmoid." The ethmoidal spine is illustrated and labeled (fig. 121). Frazer ('40. p. 197) "The upper surface of the ethmoid articulates behind with a raised part of the sphenoid connecting the two lesser wings . . ." Ethmoidal spine of the sphenoid is neither mentioned nor illustrated.

In the standard atlases Sobotta ('06, fig. 45), Jamieson ('48, pl. 52), and Grant ('51, fig. 484) show a triangular ethmoidal spine with no neck, Spalteholz ('23, fig. 66) an ethmoidal spine with a neck on the left side and without a neck on the right, and Toldt ('26, fig. 105) a quadrilateral extension of the jugum sphenoidale articulating with a non-cribriform posterior extension of the horizontal plate of the ethmoid.

Morphological considerations

Le Double (1897, p. 459) put forward a classification of human variations as (1) ''anomalies régressives, réversives, ataviques ou théromorphiques''; (2) ''anomalies progressives, évolutives ou de perfectionnement''; and (3) ''anomalies-monstruosités.'' He recorded ('03) several variations in the spheno-ethmoidal articulation in the anterior cranial fossa and compared them with the arrangement in lower animals. Some he regarded as reversive variations.

Wood Jones ('23) elaborated le Double's work and stressed the distinction between anatomical characters developed as ''basal plans of heritage'' and those developed as ''adaptations of habitus.'' He included the spheno-ethmoidal articulation, along with other features of cranial architecture, among the characters ''begot of heritage.'' Differences in the arrangement of the bones between man and non-human primates, he contended, indicated different principles of growth and a greater degree of divergence than suggested by the many structural likenesses ''begot of habitus.''

Gregory ('27) challenged the importance of these differences between man and non-human primates and considered that the basic architectural scheme showed fundamental identity of plan. The spirited controversy which followed was given a generous airing in the anthropological literature (Wood Jones, '28, and Gregory, '28).

Reference to the literature reveals little record of systematic observations to substantiate inferences of principles of growth in this region. Le Double ('03) quotes Luschka (1857), Krause (1880), Hartmann (1881), Staurenghi (1895), Sperino and Bovero (1896), Graf Spee, Szawlowski, and

Frassetto, as recording variations in the bones forming the articulation. Augier ('31) records le Double's work and points out that the variations are due to differences in the degree of completed growth of the contiguous bones. There are no figures of incidence of the different types of variation.

This relative neglect by anatomists may be due to the reluctance of museum authorities to allow large numbers of skulls to be opened. In the present study a way has been found to examine the anterior cranial fossa without alienating the goodwill of the authorities concerned.

MATERIAL AND METHODS

Australian aboriginal skulls only were examined as these are available in sufficient numbers to give statistically valid figures of variation incidence. Other ethnic groups may show different results. Skulls examined numbered 1,068. Those in which the sutural pattern could not be made out owing to breakage, unremovable foreign matter, or advanced synostosis were rejected. Data were recorded from the remaining 453 skulls, of which 52 are from the Department of Anatomy, University of Adelaide, and 401 from the South Australian Museum.

Sex of skulls was recorded according to the observer's judgment. Age was determined according to eruption of teeth and the degree of dental attrition (Campbell, '39; Abbie, '50).

The anterior cranial fossa was examined by mirror image through the foramen magnum. The source of light was the laryngoscopic attachment of a diagnostic set, the reflection being provided by a non-magnifying mirror 3 cm × 6 cm set in a specially made bracket which could be attached to the laryngoscope. This size of mirror could be passed through most foramina magna; for the others the bracket with the large mirror was replaced by a non-magnifying dental mouth mirror. Figure 1 shows the arrangement diagrammatically.

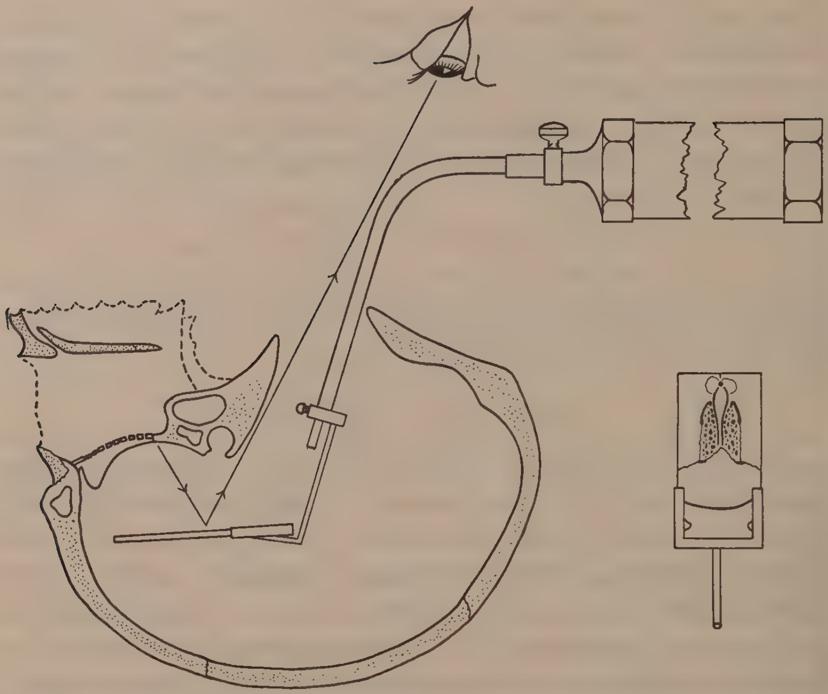


Fig. 1 Method of examining the anterior cranial fossa through the foramen magnum using laryngoscopic attachment of diagnostic set and large mirror. Scale, × ⅓. Inset: appearance as seen in reflection.

OBSERVATIONS

The arrangement of the bones entering into the spheno-ethmoidal articulation in the anterior cranial fossa is found to fall into seven different types. These are illustrated diagrammatically in figure 2, tabulated in table 1, and the incidence shown graphically in figure 3.

Variations in the contiguity of ethmoid and sphenoid bones

In Types I-IV (79%) the horizontal plate of the ethmoid is entirely cribriform and its posterior margin, with the base of the crista galli, articulates with the angled anterior margin of the ethmoidal spine of the sphenoid. In Types V-VII (21%)

there is a smooth area of non-cribriform bone behind the cribriform part which replaces the ethmoidal spine of the sphenoid and articulates along a straight transverse line directly with the jugum sphenoidale.

TABLE 1

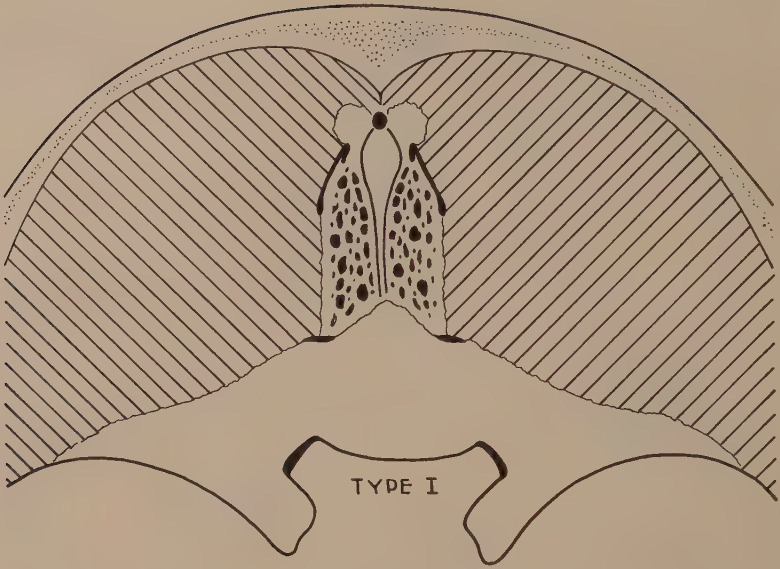
Incidence of types of variation in the spheno-ethmoidal articulation in the anterior cranial fossa of the Australian aborigine

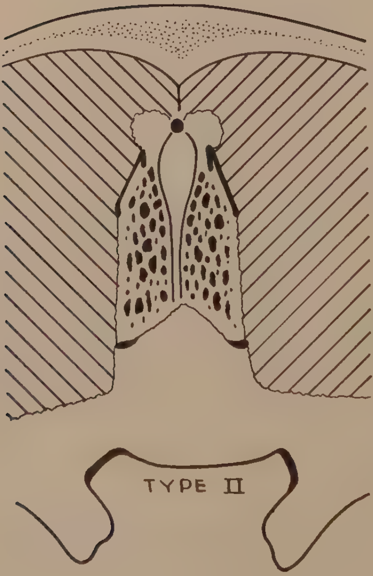
	NO. OF SKULLS	PER CENT
Type I	149	33
Type II	95	21
Type III	80	18
Type IV	34	7
Type V	51	11
Type VI	40	9
Type VII	4	1
Totals	453	100
Ethmoidal spine of sphenoid present (Types I, II, III, IV)	358	79
Ethmoidal spine of sphenoid absent (Types V, VI, VII)	95	21
Retro-ethmoid frontal suture present (Types IV, VII)	38	8

Variations in the contiguity of sphenoid and frontal bones

In Type I (33%) a triangular ethmoidal spine projects forwards in the mid-line from the jugum sphenoidale to articulate with the back of the cribriform plate. The apex of the triangle lies at the base of the crista galli and the lateral angles are at the orifices of the posterior ethmoidal canals. The sphenoid forms the major boundary of each orifice. The spheno-frontal articulation is a line running laterally from these orifices and forms the anterior boundary of large lesser wings of sphenoid.

In Type II (21%) the area of the sphenoid is reduced by right and left retro-ethmoid processes of the frontal so that the ethmoidal spine has a quadrilateral extension joining it to the jugum sphenoidale. The frontal forms the major


TYPE I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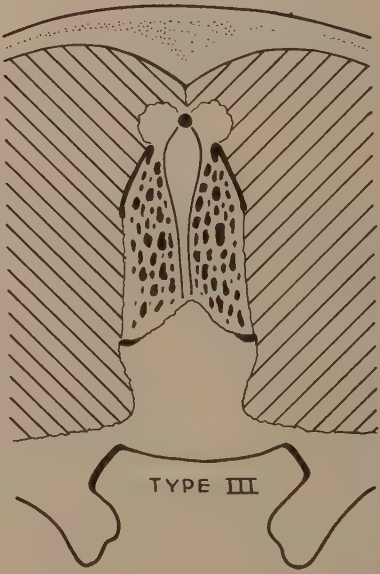
TYPE III

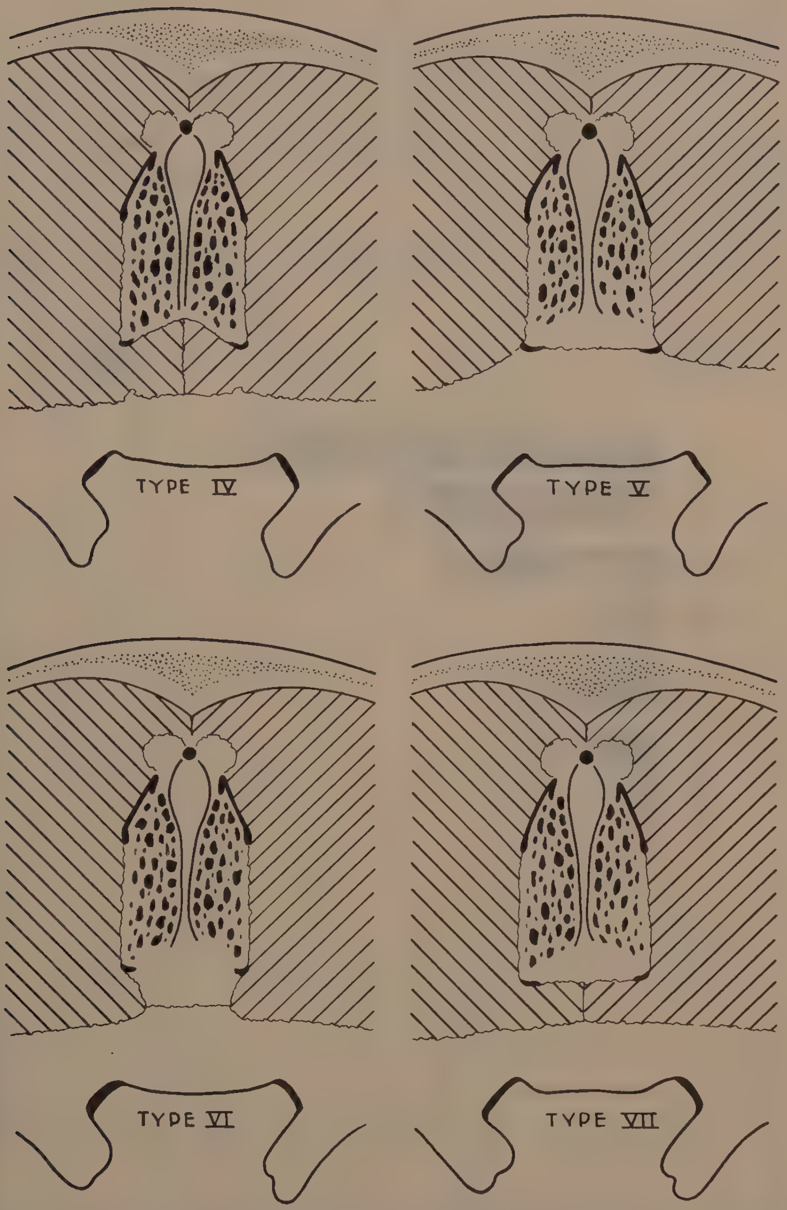

Fig. 2 Types of variation in the spheno-ethmoidal articulation in the anterior cranial fossa. Frontal bone hatched. Scale, × 1 (approx.).

boundary of each orifice of the posterior ethmoidal canals, and the lesser wings of the sphenoid are reduced in size.

In Type III (18%) the sphenoidal area is further reduced so that the ethmoidal spine appears to have developed a constricted neck. The frontal bone forms a correspondingly greater portion of the boundary of the orifices of the posterior ethmoidal canals.

In Type IV (7%) the sphenoidal area is still further reduced so that the ethmoidal spine is replaced by the retro-ethmoid processes of the frontal meeting in the mid-line to form a retro-ethmoid frontal suture. The sphenoid is excluded from the orifices of the posterior ethmoidal canals, and the frontal forms a still greater portion of the boundary.

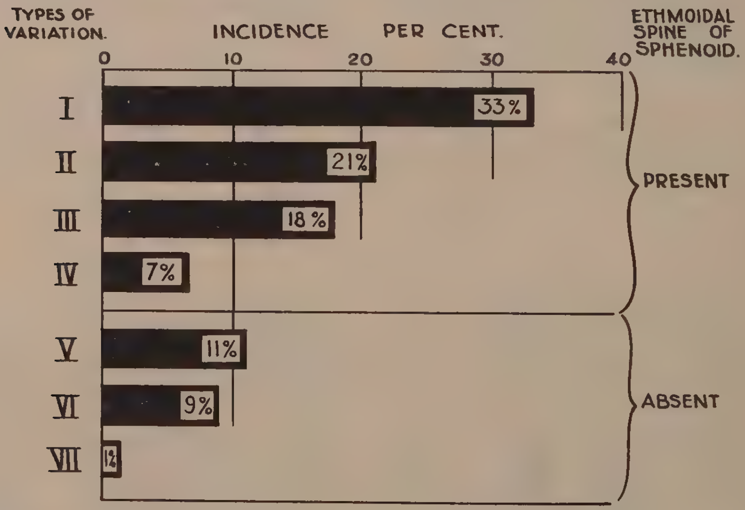

Fig. 3 Incidence of types of variation in the spheno-ethmoidal articulation in the anterior cranial fossa.

In Type V (11%) the ethmoidal spine is replaced by the posterior extension of the horizontal plate of the ethmoid. The sphenoid forms the major boundary of the orifices of the posterior ethmoidal canals, and the lesser wings of the sphenoid are large.

In Type VI (9%) the sphenoidal area is reduced by retro-ethmoid processes of the frontal and is often excluded from the orifices of the posterior ethmoidal canals. The frontal forms the major boundary of these orifices.

In Type VII (1%) the sphenoidal area is further reduced by the retro-ethmoid processes of the frontal meeting in the mid-line to form a retro-ethmoid frontal suture. The frontal forms a still greater portion of the boundary of the orifices of the posterior ethmoidal canals. It is not always possible to differentiate between Types IV and VII as the meeting of the retro-ethmoid processes hides the underlying arrangement between the sphenoid and the ethmoid.

Effect of sex and age on incidence of variations

Data on skulls estimated to be male (245) and female (160) were recorded separately. Data on young (90) and old (116) skulls were also recorded separately. Skulls of juveniles, adolescents, and those with Broca's Grade I attrition were classified as young, while those with Broca's Grade IV attrition were classified as old. The intermediate group with Broca's Grades II and III attrition were excluded from this part of the investigation. Table 2 shows the results along with percentage incidence and comparison with the total series.

TABLE 2

Incidence of types of variation in the spheno-ethmoidal articulation in male, female, young and old skulls, compared with the total series

	MALES		FEMALES		YOUNG		OLD		TOTAL SERIES	
		%		%		%		%		%
Type I	95	(38)	40	(25)	28	(31)	47	(40)	149	(33)
Type II	46	(19)	38	(24)	18	(20)	22	(19)	95	(21)
Type III	44	(18)	33	(21)	13	(14)	23	(20)	80	(18)
Type IV	20	(8)	11	(7)	5	(6)	10	(9)	34	(7)
Type V	22	(9)	14	(9)	20	(22)	7	(6)	51	(11)
Type VI	16	(7)	22	(13)	6	(7)	7	(6)	40	(9)
Type VII	2	(1)	2	(1)	0	(0)	0	(0)	4	(1)
Totals	245	(100)	160	(100)	90	(100)	116	(100)	453	(100)

Additional observation

Variation in the contiguity of ethmoid and frontal bones

Two cases out of the series of 453 showed the arrangement illustrated diagrammatically in figure 4. These have been recorded as Type I for the spheno-ethmoidal articulation. In addition, however, the horizontal plate of the ethmoid has a non-cribriform lateral extension between the orifices of the anterior and posterior ethmoidal canals which replaces part of the orbital plate of the frontal. The sphenoid forms a long overhanging lip of the posterior ethmoidal canal.

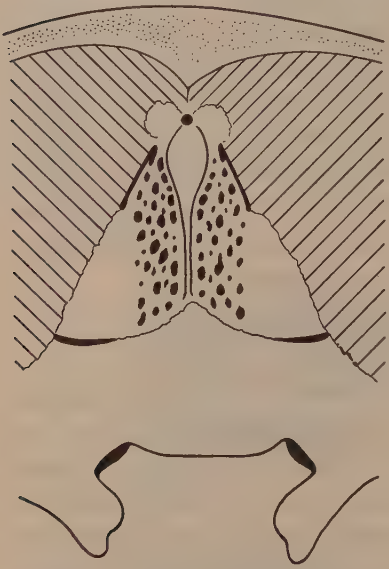

Fig. 4 Rare variation due to hypo-development of orbital plate of frontal bone. Scale, × 1.

DISCUSSION

These observations can be correlated with the embryology of the region. The primitive chondrocranium in relation to the anterior cranial fossa consists of a spheno-ethmoidal cartilage with a cribriform part separated from the rest by an orbito-nasal fissure. Vessels and nerves to the primordial membranous cranium in this region come through this fissure, the parent vessels and nerves being in the developing orbit. As the cribriform plate ossifies, part of the spheno-ethmoidal cartilage is resorbed and replaced by bone from the descending orbital plates of the frontal. These plates, developed in membrane, roof the orbit, the ethmoidal air cells, and the anterior and posterior ethmoidal canals. Thus the orifices of these canals must lie in the suture between the ethmoid and frontal bones.

The present study shows that these descending orbital plates usually (44% incidence) end in the situation indicated in Type I or V. If they over-shoot the mark they give rise to the variations recorded as Types II, III and IV, or VI and VII, depending on the extent of the hyper-development. The apparent degree of variation is greater than the real for the sphenoid and frontal "glissent l'un sous l'autre, s'articulent en biseau" (Augier). If they do not reach the mark (twice in 453 in this series), the variation noted in figure 4 occurs. Augier ('31) quotes Calori (1892) as recording a similar case of frontal hypo-development.

The large incidence of Type I suggests that this is the mode. The law of normal variation is broken, however, in that the variations are practically all associated with hyper-development of the frontal bones, while hypo-development was seen only twice in the entire series. This may be due to the specific functions of the frontal in roofing the orbit, the labyrinth, and the ethmoidal canals in the first region, whereas in the second it matters little which bones occupy the space.

In whatever way genetic factors influence differential growth of ethmoid, sphenoid and frontal bones, there is seen here an example in miniature of the variable "physical mosaic" (Abbie, '52). The smoothness of the curve of incidence from the norm to the extreme variations indicates that these are modifications and not mutations.

Le Double ('03) compares the ethmoidal spine of the sphenoid as seen in the human subject with the shape in lower animals and suggests that its presence is a reversive variation. He considers, without quoting figures to substantiate the statement, that its absence, with the anterior border of the jugum sphenoidale ending in a straight line (Type V in fig. 2) is the usual human arrangement, "dans la race blanche, du moins." The present investigation, however, shows a 79% incidence of the presence of the ethmoidal spine which must then be accepted as the most common arrangement in the Australian aborigine, at least.

The extreme variation of retro-ethmoid frontal suture appealed to the imagination of the earlier writers. Le Double quotes Staurenghi (1895) as recording it in a negro delinquent but searching in vain in another 233 skulls. Le Double himself records a case in ''une démente'' and a vain search in another 191 skulls, and he quotes Frossarri as seeing it twice in 177 skulls. He regards it as a reversive variation.

Wood Jones ('29) discusses the relatively much greater development of the frontal bone in the anterior cranial fossa in the non-human primates than in man. He suggests that, in the pithecoid stock, the enlarged orbits probably became established before the enlargement of the anterior portion of the cerebral hemispheres was fully initiated and the dominant role played by the frontal in roofing the orbit gave rise to this difference. Thus the pithecoid method of cranial expansion is by membrane bone over an already reduced chondrocranium. In the human stock, he suggests, the frontal cerebral enlargement probably started at an earlier stage, and that possibly a diurnal habit and only moderately enlarged orbits were also factors in retaining the primitive articulation of the bones during the period of cranial expansion. Thus man retains the primitively large chondrocranium as well as the enlargement of the membrane bones. He gives no figures of incidence and types of variation either in man or in the primates but considers a retro-ethmoid frontal suture as being ''excessively rare'' in man.

Augier ('31) records most of the variations found in this investigation but gives no figures of incidence. He believes that any variation in this region is of no fundamental importance, but each merely the result of a contest between the bones for the available territory. This view is supported by de Beer ('37) who regards the various types as natural experiments of variation in the extent of the bones.

Ashley Montagu ('43) reports the incidence of spheno-ethmoidal contact in the anterior cranial fossa of the non-human primates. This is present in the orang-utan 26 times in 26 specimens (100%), in the chimpanzee 22 in 26 (84.6%), in the gorilla 8 in 17 (47%), and in the gibbon not at all in 9 specimens (0%). In the remainder the retro-ethmoid frontal suture is present. He disagrees with Wood-Jones's inferences and suggests that the extent of the frontal involvement in the anterior cranial fossa is directly proportional to the prognathism of the species.

Le Gros Clark ('47) notes that *Australopithecus* has a "probable" spheno-ethmoidal contact in the anterior cranial fossa, implying that this is suggestive of human kinship.

Butler ('49) reports the occurrence of a retro-ethmoid frontal suture in the anterior cranial fossa in 6 of 25 (24%) human skulls "from Bengal," which the other cranial characters show to be a "homogeneous group." He found no correlation of the suture with sex, age, or cephalic or gnathic index.

Gregory ('52) says that a retro-ethmoid frontal suture, absent in the young gorilla, develops in the adult animal as a structural adjustment, affording a firm base for the immense supraorbital ridges. He notes that this suture is a superficial thing overlying the primary cartilaginous joint union of the sphenoid and ethmoid beneath.

The present study shows that cases where the frontal bone forms a retro-ethmoid frontal suture (Type IV plus Type VII) amount to 8%, with a standard error of ± 0.4%, in the Australian aborigine. This cannot be regarded as excessively rare. The scanty literature suggests that it is higher than in European skulls, but lower than in a small series of skulls from Bengal of unspecified ethnic group. While of questionable statistical value the Bengal series shows a standard error of ± 9%, so that the expected incidence in a large series would be theoretically between 15% and 33%.

The figures of incidence of the different types of variation show that retro-ethmoid frontal suture is the extreme degree of a process which shows a trend towards it in a much higher proportion of cases.

Table 2 suggests that sex and age have no significance in the variation incidence. The general trend appears to be the same and differences may be due to the smaller numbers in some groups.

It seems fruitless to add more speculation on the ethnological and phylogenetic significance of these figures without records of additional systematic observations on statistically valid numbers of other ethnic groups and of the non-human primates.

SUMMARY

1. A record is presented of the types and incidence of variations in the spheno-ethmoidal articulation in the anterior cranial fossa of 453 Australian aboriginal skulls, examined by illuminated mirror.

2. Seventy-nine per cent show the horizontal plate of the ethmoid ending with the cribriform plate (Types I, II, III, and IV). Twenty-one per cent show a posterior ethmoidal extension of smooth bone which replaces the ethmoidal spine of the sphenoid (Types V, VI, and VII).

3. Type I (33%) is the most common arrangement. Hyper-development of the orbital plate of the frontal bone at the expense of the sphenoid shows alteration in the arrangement of progressive extent but decreasing incidence in Type II (21%) and Type III (18%), culminating in a retro-ethmoid frontal suture in Type IV (7%). Hypo-development of the orbital plate of the frontal bone occurs twice in 453 cases, the deficiency being made up by non-cribriform lateral extensions of the horizontal plate of the ethmoid (fig. 4).

4. A parallel process is seen in the cases where the posterior extension of the horizontal plate of the ethmoid replaces the ethmoidal spine of the sphenoid. Type V (11%) is altered by frontal hyper-development to Type VI (9%) culminating in a retro-ethmoid frontal suture in Type VII (1%).

5. Thus 8% (Type IV plus Type VII) show retro-ethmoid frontal suture separating, on this aspect, the ethmoid from the sphenoid.

ACKNOWLEDGMENTS

Grateful thanks are due to Professor A. A. Abbie for suggesting this investigation and for constant advice. Professor A. Schultz, of Zurich, suggested the use of an illuminated mirror. The Director and Ethnologist of the South Australian Museum have kindly afforded access to material, while Mr. Peter Kempster and Miss Gwen Walsh have supplied respectively technical and artistic help.

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MODIFICATION OF SKULL AND JAW ARCHITECTURE FOLLOWING REMOVAL OF THE MASSETER MUSCLE IN THE RAT[1]

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SIX FIGURES

INTRODUCTION

Experimental interference with masseter muscle function in the rat has been reported twice in recent years. Pratt ('42) described extreme skeletal distortions following removal of the masseter muscle and a portion of the zygomatic arch in one-day-old rats. The severity of the changes was attributed to two factors: interruption of the arch and the early age of the animals at the time of operation. The first of these was subjected to further analysis by Washburn ('46), who removed various portions of the zygomatic arch, but no muscle tissue, in one-day-old rats: skeletal asymmetries comparable to those observed by Pratt followed only when more than half of the arch had been removed.

The procedures in this study differ from those of previous investigators in two respects: (1) the masseter muscle only was removed; the entire zygomatic arch was carefully retained in all cases: (2) operations were performed on 30-day-old rats, rather than on newborn animals. A previous study by the authors ('51) has shown that interference with muscle function in one-month-old rats produces skeletal alterations comparable to those which result from similar operations (Washburn, '47) on newborn animals.

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[1] Read before the New York Section of the International Association for Dental Research, May 26, 1952.

METHODS AND TECHNIQUES

Twenty-four Sherman strain rats from 4 litters were used in this experimental study. The masseter muscle was removed under intraperitoneal pentabarbital anesthesia in 12 animals at the age of about 30 days: an equal number of littermates served as control animals. The masseter was removed unilaterally in 9 of the operated group (always on the right side), and bilaterally in three animals.

The skin was incised along a line which extended inferiorly from a point anterior to the external ear to the lower border of the mandible at the angular process. A second incision was made in an anterior direction, terminating close to the angle of the mouth, which was not cut. The masseter muscle and the associated structures were then exposed after reflecting the skin and superficial fascia. The masseter was elevated from the mandible by blunt dissection and cut. All of the muscle was removed with the exception of some fibers arising on the medial surface of the zygomatic arch (the posterior deep part, Greene, '35), and a few fibers arising in the infraorbital area (the anterior deep part, Greene, '35). The zygomatic arch, parotid gland, and facial nerve remained intact. The tissues were closed with interrupted silk or nylon sutures.

Operated and control animals subsisted under identical laboratory conditions on a diet consisting of *ad lib* McCollum rat diets,[4] purina chow biscuits and lettuce. The operated animals were maintained on this regimen at weights corresponding to those of the littermate controls. An initial postoperative weight loss suffered by the experimental animals was usually regained within one month following operation. All the animals were sacrificed at approximately 5 months of age and subjected to gross examination; the heads were preserved for further study. Roentgenograms of the mandible were obtained on spectroscopic plates (Applebaum et al., '33).

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[4] McCollum rat diet proportions: Ground corn 15; wheat 15; barley 15; rolled oats 15; soybean meal 15; meat scraps 10; whole milk 5; skim milk 5; sodium chloride 2; calcium carbonate ½.

RESULTS

Gross modifications in the form of the skull, the mandible and the dental arches of the maxilla and mandible occur as the result of unilateral masseterectomy in the young rat. A brief summary of these changes follows:

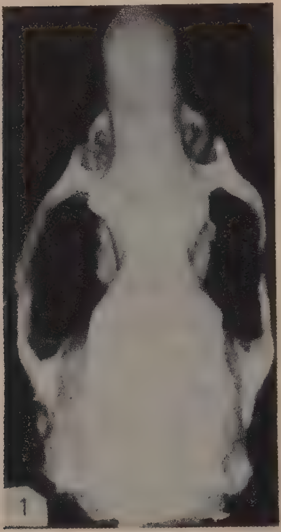
Skull. The rostrum deviates toward the unoperated side anterior to the fronto-nasal suture; both the nasal and the premaxillary bones are affected by this change (figs. 1–2).

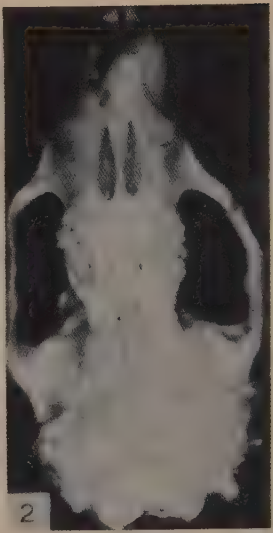
The sweep of the zygomatic arch is considerably reduced on the operated side; the entire arch is closer to the cranium, and the zygomatic bone proper is exceedingly thin (fig. 1). The anterior palatine foramina, usually found in bilaterally symmetrical locations in the control animals, varied in the operated animals; the foramen on the operated side lies further posterior than that of the unoperated side (fig. 2).

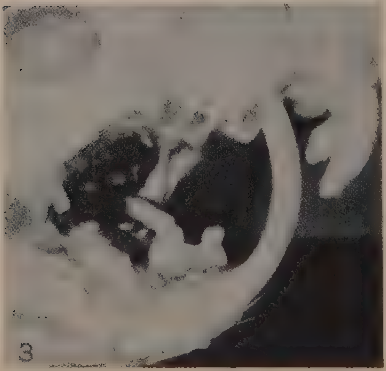
Mandible. The body of the mandible on the operated side bends sharply downward and laterally in the region of the third molar tooth; the angular process is blunt, and altered by a pronounced medial deflection; and a characteristic remodeling occurs in the ascending ramus, with corresponding alterations of the internal architecture. The mandible on the operated side is reduced in size, especially in the superior-inferior dimensions of the ramus (from the sigmoid notch to the lower border); a smaller reduction in size is seen in the condyle-lower incisor alveolus length (figs. 5–6).

The dental arch. A "bowing" of the maxillary arch occurs on the operated side (fig. 2), and the occlusal relationships of the teeth are severely affected on both sides. The first and second molar teeth of the maxilla and mandible do not occlude on the operated side,—"open bite" (fig. 3); the remaining molar teeth meet in a shearing manner,—"cross bite." The incisor teeth deviate toward the operated side (fig. 4).

The teeth of the operated animals, viewed under the dissecting microscope, show almost no evidence of attrition; extensive alveolar atrophy is apparent, especially in the region of the molar teeth. The histologic dental and periodontal findings are discussed in detail elsewhere (authors, '55).







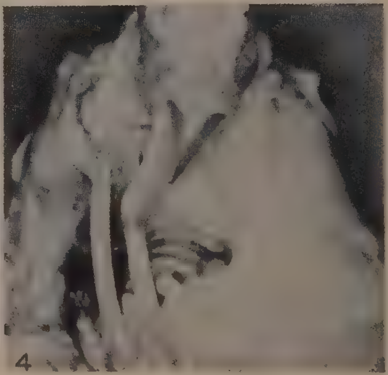


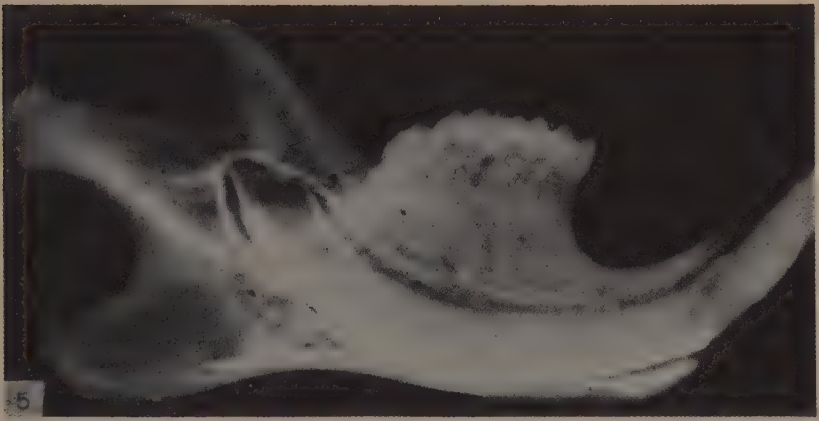
Fig. 1 Dorsal view of the cleared skull of an experimental animal which was sacrificed approximately 4 months following removal of the right masseter muscle. The rostrum is deflected to the left side anterior to the fronto-nasal suture; the zygomatic arch of the right side is flatter, closer to the cranium, and not as well formed as the arch of the unoperated side.

Fig. 2 Ventral view of the skull shown in figure 1. The dental arch is "bowed" on the right side; the anterior palatine foramen is relatively posterior on that side.

Fig. 3 Gross fixed specimen. Right side of an experimental animal in which the right masseter had been removed. The teeth have been stained for contrast. Warping of the mandible has caused an "open bite" in the first and second molar region; occlusion of the incisors is impaired.

Fig. 4 Anterior view of the same specimen shown in figure 3. Both the maxillary and mandibular incisor teeth deviate to the operated side.

Removal of the masseter muscle bilaterally produces none of the extreme variations in skeletal structure or dental occlusion described above; a slight opening of the bite occurs bilaterally in the first molar area. No gross alterations in the skull or dentition were observed in the bilaterally operated animals.



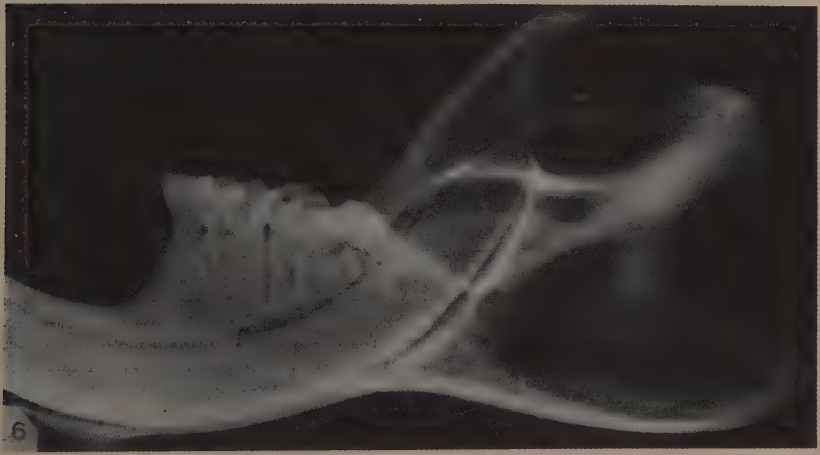


Fig. 5 Roentgenogram of the right mandible of an experimental animal in which the right masseter muscle had been removed. (Compare proportions and trabeculation pattern with figure 6.)

Fig. 6 Left mandible of the animal shown in figure 5. The mandible of the unoperated side is indistinguishable from those of the control animals.

DISCUSSION

The results of this study demonstrate that rostral deviation of the skull (reported previously by earlier workers, and by ourselves) occurs when masseter muscle function is impaired unilaterally. The deviation results from inhibiting muscle function, either by the surgical removal of the muscle, or by the elimination of the zygomatic arch, the principal skeletal origin of the masseter. The zygomatic arch seems to play a minor role, if any, in the resulting deformity. The sequence by which the rostrum is pulled around to the unoperated side following masseterectomy is not evident. It would seem, however, that unilateral removal of the masseter (the largest and most powerful element of the cranio-facial musculature of the rat), causes sufficient discrepancy in the balance of the masticatory apparatus to affect bilateral symmetry in the underlying skeletal structures. It is of interest that similar rostral deviations, non-specific as to side, have been reported in rats following extensive alteration in the calcium-phosphorus ratio of the diet (Heston, '38). In Heston's studies, also, the mechanism by which the deviation is achieved is not clear, although he hypothesized that growth rate and genetic factors play a role in the production of the resultant "bent-nose" condition.

Imbalance in the masticatory muscle system also produces additional variations. For example, the warping of the mandible of the operated side follows unilateral removal of the masseter. Perhaps the digastric muscle, in the absence of masseter, tends to rotate the jaw toward the unoperated side. It is probable that the inferior and posterior pull of the digastric muscle may be an important factor in the remodeling of the body of the jaw, so that the lower molar teeth no longer occlude with their maxillary antagonists, thus creating an "open bite" condition. Comparable alterations in the mandibular architecture of man have been reported following removal of the mandibular condyles (Brodie, '41).

Other variations from the normal structural pattern, which were observed in the operated animals, may be attributed to diminished functional stimuli. Loss of alveolar bone support, especially in the region of the "open bite" molar teeth on the operated side, and failure of the zygomatic arch and mandible to attain normal proportions are examples of such changes.

Because alterations which occur following unilateral removal of the masseter seem to result from asymmetrical muscle function, it is not surprising to find so little morphologic variation from the normal in animals which have undergone bilateral removal of the masseter. Imbalance in the masticatory muscle system would thus seem to be the principal cause of modifications observed in the skull and jaw architecture, and also in the dental occlusion of the rat.

SUMMARY AND CONCLUSIONS

1. The masseter muscle was surgically excised in a number of one-month-old Sherman strain rats.
2. Unilateral removal of the masseter results in severe skeletal alterations in the skull, jaws, and dental arches.
3. The rostrum deviates to the unoperated side; the mandible on that side becomes warped in an inferior and lateral direction.
4. Molar tooth occlusion is affected on both sides of the mouth, an "open bite" resulting on the side of operation.
5. No marked gross or dental changes follow bilateral removal of the masseter muscle.
6. Architectural variations in the cranio-facial skeleton following unilateral removal of the masseter muscle in the rat are probably the result of functional imbalance in the remaining masticatory muscles.

The authors are indebted to Dr. Barnet M. Levy, Director of Research, School of Dental and Oral Surgery, Columbia University, for his aid in carrying out this study.

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CONFIGURATION AND LATERAL CLOSURE OF THE SUPERIOR ORBITAL FISSURE

WHITES AND AMERICAN NEGROES OF BOTH SEXES

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TWELVE FIGURES

INTRODUCTION

It is now well known that there are differences in the size, contour and configuration of the orbit. These variations have been noted for races and sexes.

The superior orbital fissure presents a variety of configurations in different crania; its lateral closure is described variously in text books, which differences may be accounted for by skulls from different races and sexes. A search of the literature revealed but one reference to racial differences in the overall configuration of the superior orbital fissure; Gallemaerts (1897) studied the fissure in 160 skulls of various races and groups. He summarized three types: (1) the commonest type, with two segments, one narrow, the other broad; (2) a type with both segments broad; and (3) a triangular type.

Generally, the superior orbital fissure is described as the gap between the greater and lesser wings of the sphenoid bone, closed at its lateral extremity by the frontal bone. It represents the separation between the roof and lateral wall in the posterior third of the orbit. It consists of two rather distinct segments: a broad medial part lying next to the bridge which separates it from the optic foramen, and a narrower lateral limb (Whitnall, '32). Gallemaerts (1897) reports the length of the fissure to be most often 15 to 16 mm, with the lateral segment measuring 9 or 10 mm. He noted that the lateral segment is shorter and wider in Negroes than in Whites; the entire superior orbital fissure is reduced to a lozenge shape in the gorilla and to an oval in the gibbon. No sexual differences were mentioned.

MATERIAL AND METHODS

Approximately 750 cards listing skeletal specimens were surveyed from the listings of the Todd collection. These specimens were those deposited in the anatomical laboratory of Western Research University. Generally Todd ('28) points out that the population represents, in no certain way, stable American stock, but is nevertheless allied to the Army populations of Davenport and Love. Todd states that since the Negro population was, or is largely of Southern origin, the problem of admixture with Whites is more nearly insignificant. From the argument asserted by Todd, it can be assumed that the Negro specimens represent the American Negro in general. Whether or not this sample may be taken as reliably standing for Negroes of the African Continent is open to question.

The collection contains a greater number of Negroes and males than Whites and females, as would be expected. Therefore, the total number of Negroes and males was held back to a general level nearer that of Whites and females.

The cards were selected from the files in a range of ages from *circa* 20 to 40 years. This range of necessity would be an approximate one since the exact chronological age of many specimens was unknown and skeletal age was the only available criterion. Several specimens were removed from the original list of cards selected for several reasons, namely: (1) ossification of the area in question was too advanced or indistinct; (2) pre- and post-mortem trauma had involved, frequently ruining, the area; and (3) though quite infrequent, the numbers on the box and the contained calvarium did not coincide.

For the reasons listed above, the final sample consisted of: White, 202 (157 males and 45 females); and Negro, 328 (224 males and 104 females); total, 530 specimens.

Each cranium was carefully examined and the configuration of each superior orbital fissure was noted. The configuration, *i.e.*, the general outline or silhouette, of the superior orbital fissure is determined by the combined outlines of both medial and lateral segments. The medial segment proved to be the least variable of the two, showing more variation in size than in contour. Therefore, by configuration, as used here, the reference is directed to the lateral segment; in actuality, it is the configuration of lateral closure of the fissure. The superior-inferior diameter of the fissure, or its lateral segment, is not directly indicated by the classification as given here — except in the case of the score wide/blunt, where a given fissure measured greater than 1 cm in this diameter. Figures 1 to 6 demonstrate the typical criteria for scoring form of lateral closure, *i.e.*, configuration: 1 — point, 2 — square, 3 — round, 4 — oval, 5 — cul-de-sac, and an additional scoring of the configuration of the entire fissure, 6 — wide/blunt. Each orbit, right and left, was scored separately. In addition, the bones contributing to the lateral closure were noted: whether between greater and lesser wings of the sphenoid, between greater wing and frontal bone, in the greater wing, or in the frontal bone; figures 7 to 12 illustrate some of these closures.

Orbits of each skull, right and left, were compared for sameness, minor differences, and marked differences. Where a configuration of the superior orbital fissure or its closure approached a transition between two scoring criteria, it was recorded as a subscript and one-half value was given to each of the two categories in the final analysis. When such a transition of scoring occurred in only one of the two orbits, it was considered a minor difference between them and recorded as such in the data. In fissures presenting a superior to inferior diameter of 1 cm or more, an additional score, wide/blunt, was given. This additional scoring does not appear in the tables as additive to the configuration scores, *per se*, since it indicates occurrence of an overall configuration of the entire fissure and not of the lateral closure alone.

Observations were also made on a series of anthropoid skulls, consisting of 6 gorillas, 3 chimpanzees, 3 orangs, 2 gibbons, and 1 baboon.

TABLE 1

Superior orbital fissure configurations in 530 crania given as percentages according to race and sex

RACE	SEX	CONFIGURATION OF SUPERIOR ORBITAL FISSURES						SIMILARITY IN R. AND L. ORBITS		
		P	S	R	O	C	W/B	S	Dm	D
W	M	38.7	31.5	17.3	7.6	5.2	9.2	66.2	17.7	16.1
W	F	57.7	18.6	11.5	3.2	7.7	2.6	74.4	18.0	7.7
N	M	30.4	21.2	36.8	4.6	6.2	9.7	62.5	10.3	27.2
N	F	41.6	24.7	25.2	1.9	7.0	5.8	60.0	11.5	28.8
Means		42.1	22.8	24.0	4.4	6.6	6.8	65.8	14.4	20.0

Configurations: P — point, S — square, R — round, O — oval, C — cul-de-sac. Overall configuration, W/B — wide blunt. (See figs. 1–6.)

Similarity in orbits: S — similar, Dm — differ only to a minor degree, D — markedly different.

RESULTS AND DISCUSSION

Tables 1 and 2 summarize, in per cent, the types of configuration of the superior orbital fissure and of lateral closure for each of the 4 groups of crania. Percentages total 100 each for configurations of superior orbital fissures, for lateral closure, and for similarity in right and left orbits; the additional score, wide/blunt, is treated separately, *i.e.*, the figures given in its column represent the percentage of fissures demonstrating that characteristic alone.

The tables represent combined scores for right and left fissures of each cranium within the group. Combining these scores, in order to simplify the tabular material, is justified on the basis of the high degree of similarity between orbits of the same cranium, as demonstrated in the similarity columns.

Scoring symbols for the configuration of superior orbital fissures indicate the characteristic form which the fissures show, in the lateral segment, at and near the actual lateral segment, at and near the actual lateral closure. Where the superior-inferior diameter was in excess of 1 cm, an additional score, wide/blunt, was given the configuration. In each such case the lateral segment was as wide as the medial and the configuration of the lateral closure was round or oval, as would be expected. The score, cul-de-sac, indicates a separate category whose form may be closely allied to any one or all of the other forms except those additionally scored wide/blunt; the presence of this cul-de-sac, a foramen-like closure, renders the configuration unscorable according to the present categories as mentioned. (While the significance of the cul-de-sac formation is unknown to us, there may be some relationship with the presence of notable foramina, presumably venous, lateral to the closure of the fissure.) Wherever one form had a more lateral extension of the termination in a narrowed slit, *e.g.*, an oval form with a point

TABLE 2

Lateral closure of superior orbital fissures in orbits of 530 crania given as percentages

RACE	SEX	LATERAL CLOSURE				SIMILARITY IN R. AND L. ORBITS		
		G/F	G/L	G	F	S	Dm	D
W	M	79.3	10.8	9.8	0.4	71.4	19.1	8.3
W	F	79.5	16.1	4.5	0.0	71.2	20.0	8.9
N	M	72.3	9.4	18.3	1.0	71.2	20.1	8.7
N	F	78.4	14.2	7.4	0.0	71.2	20.2	7.7
Means		77.3	12.7	9.9	0.4	71.2	19.8	8.4

Lateral closures listed are: G/F — between greater wing of sphenoid and frontal bone.
G/L — between greater and lesser wings of sphenoid.
G — within greater wing alone.
F — within frontal bone alone.
(Criteria of similarity in orbits same as given in table 1.)

termination (see fig. 7), a one-half score was given this extension in the final compilation of data. This extension of the termination, however, not a frequent finding, represents but a minor problem in scoring.

The data given here may be compared with that of Gallemaerts (1897). It should be kept in mind that the configurations listed, beginning with the point closure and progressing to the oval form, indicate a continuum of progressive widening of this lateral segment. Gallemaerts' type 1 fissure would be exemplified in the configurations listed as point, square, round, oval and cul-de-sac. A type 2 would be demonstrated by those fissures scored as wide/blunt and a few others, not separately treated in the present data, where the two segments were of equal size but less than 1 cm in superior-inferior diameter. The type 3, triangular, is considered by this scoring schedule to be an uncorrelated scoring form, a combination score, as it were; it does not indicate a frequent finding.

Data given here concerning the lateral closure of the superior orbital fissures, a critique of the bony contributions to the lateral closure, demonstrate greater similarity from group to group.

Most notable in our results, there appear two divergent groups in configuration of fissures, *viz.*, those characteristic of Negro males and those characteristic of White females. In the former, one finds the greatest number of widened lateral configurations; and in the latter, the greatest number of narrowed, pointed, closures. Fissures of White males and Negro females fall into a somewhat less clearly marked differentiation. Other differences and similarities from group to group may also be noted in the table. In lateral closure the two divergencies are again notable, especially in the greater wing of the sphenoid bone. Following the assumption that an anatomical variation which occurs in less than 10% of a series is insignificant, or at least unusual, Negro males represent the only group in this study which fall below this level in having the lateral closure of the superior orbital fissure between greater and lesser wings of the sphenoid, and the only group above this level in closure within the greater wing.

The White group demonstrates a greater similarity between fissures of the same cranium than does the Negro group, as far as configuration is concerned; whereas both races and sexes show remarkable similarity in lateral closure, between the fissures of the same cranium.

In the group of 15 anthropoid specimens which were examined concurrently with the human crania, it was noted that the fissures invariably showed the wide/blunt overall configuration with the form of lateral closure approximately equally distributed between oval and round terminations; one-half of these specimens had slit-like (point) lateral extensions to the terminations (see note above on half scores). Species of animal, age of animal or size of skull had no apparent effect in determining the variations of the fissures observed in the anthropoid group. Such a distribution of configurations was likened by Gallemaerts (1897) to that of the Negro male.

In the process of examining the fissures, we frequently observed a groove extending across the orbital surface of the greater wing inferiorly and medially from the cul-de-sac formation. In many cases where no cul-de-sac was found, this groove extended from the inferior border of the lateral segment of the fissure to the region of the junction of superior and inferior orbital fissures. This groove appears to divide, roughly, the thinned-out medial portion of the greater wing from the thickened remainder. See figures 8, 9, and 12. Inspection of several 7-month (prenatal) skulls showed that narrowing of the fissure takes place after this time and this groove may indicate the line from which a thin shelf of bone grows medially to narrow the fissure. Because of the occurrence of the wide fissure in the fetus and in anthropoids it may be regarded as a phylogenetically earlier type. Away from point configurations and in the direction of wide/blunt may be regarded as a pedomorphic feature.

It would be interesting to know if there is any correlation between a wide fissure and characteristics which have been regarded as "fetal": yellowish skin, hairlessness and peppercorn hair.

SUMMARY

In this study 530 male and female, White and Negro crania are classified according to configuration and lateral closure of the superior orbital fissure. The degree of similarity between fissures of the same cranium is noted. Interrelationships of the variations with race and sex are demonstrated. The greatest divergence shown between any groups, as to configuration and closure, is found between Negro males and White females. The former group shows the greatest number of widened configurations; the latter, the greatest number of narrowed, pointed, configurations. Similarly this divergence is noted in lateral closure. Fifteen anthropoid specimens are included and the configuration of the fissures discussed. Widening and blunting of the fissure, as a phylogenetically early type, is suggested.

ACKNOWLEDGMENT

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PLATES

PLATE 1

Diagrammatic drawings of right orbits to demonstrate the scoring criteria for configurations of superior orbital fissures.

1 Point

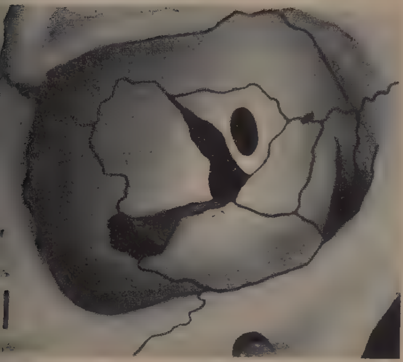
2 Square

3 Round

4 Oval

5 Cul-de-sac

6 Wide and blunt



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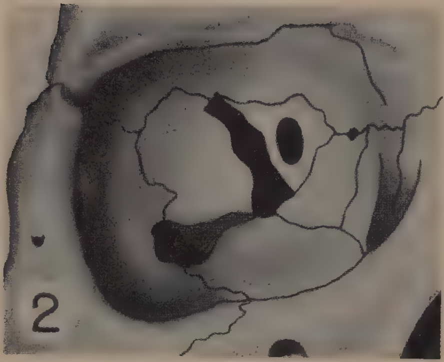

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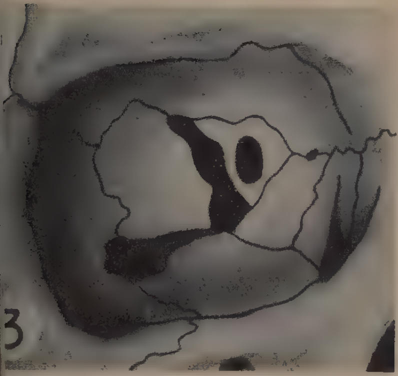

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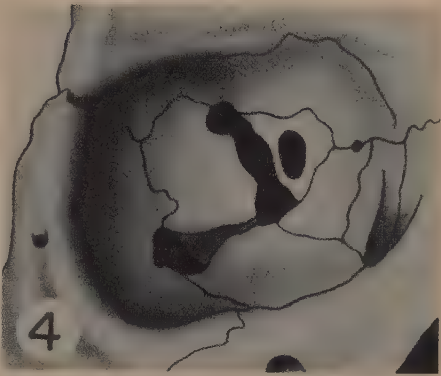

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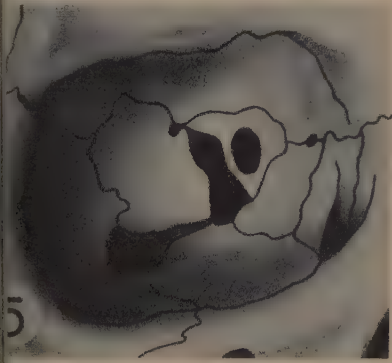

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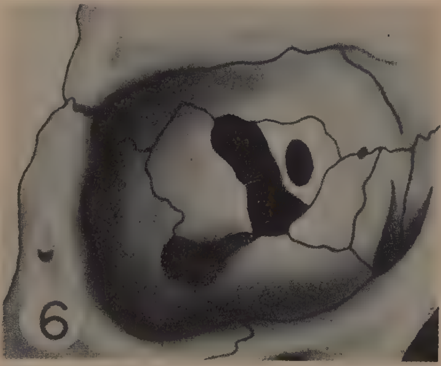


6

PLATE 2

A series of retouched photographs of right and left orbits to demonstrate certain unusual forms of lateral closure of superior orbital fissures.

7 Right orbit, showing lateral closure as a square and a lateral extension as a point (ending in the frontal bone). Without the pointed extension into the frontal bone, this would be considered to be a typical closure between the frontal and greater wing of the sphenoid.

8 Left orbit, cul-de-sac in the greater wing of the sphenoid.

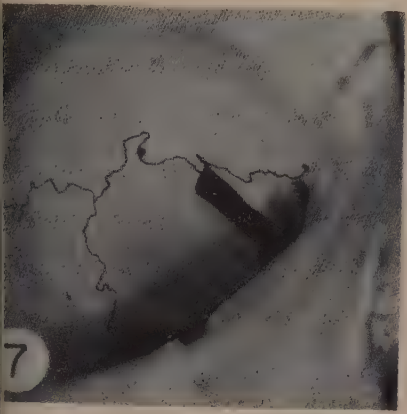
9 Right orbit, square-oval in the greater wing.

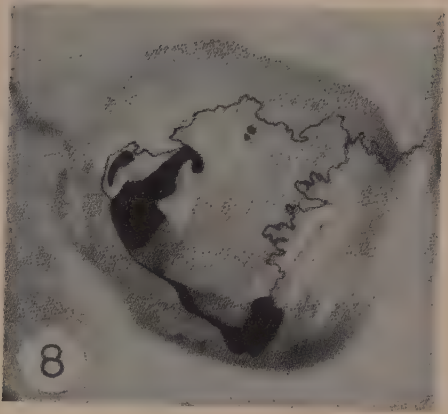
10 Left orbit, small round in the junction of greater and lesser wings, also showing a Wormian bone at the closure.

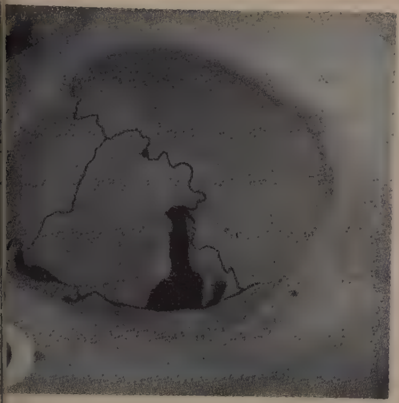
11 Left orbit, cul-de-sac at the junction of wings and frontal bone.

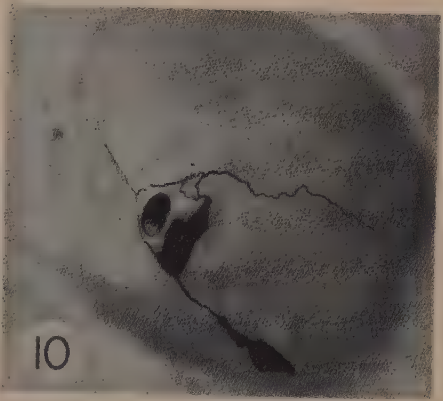
12 Left orbit, cul-de-sac in the greater wings at the junction of wings.

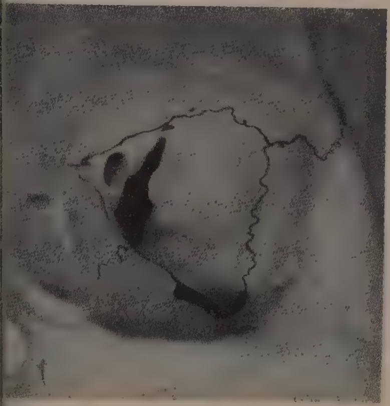
PLATE 2

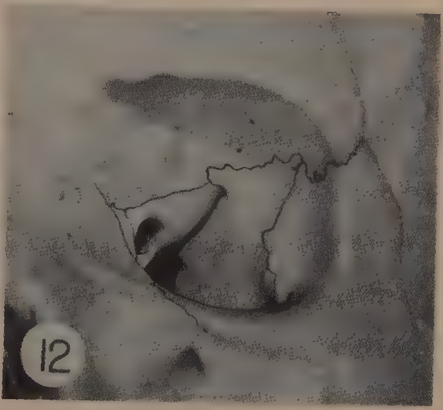












ON THE KELL-CELLANO (K-k) BLOOD GROUP: THE DISTRIBUTION OF ITS GENES IN THE WHITE POPULATION OF MANITOBA

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INTRODUCTION

In 1946 Coombs, Mourant and Race ('46) described briefly the case of a three-week-old baby with anemia, whose blood was compatible with that of its father and its mother in all the blood groups known at that time, but whose cells gave a positive direct Coombs' reaction. The mother's serum agglutinated the father's cells. Later in the year Race ('46) referred to the blood group system defined by the antibody in the mother's serum as "Kell," and said that the antibody agglutinated about 7% of random bloods. Many anti-*Kell* sera have since been found. For identification the individual examples are known by an abbreviation of the donor's name, eg., Kell, Driz, Si, And, Ram, etc. In the absence of clear cut evidence to the contrary these have been considered to be of identical specificity, although Race and Sanger ('50) raised the question of non-identity.

In 1949 Levine, Backer, Wigod and Ponder ('49) discovered an antibody that reacted with all *Kell*-negative and a proportion of *Kell*-positive bloods. They called the so-defined antigen "Cellano," and deduced from their observations that anti-*Cellano* defined an antigen allelic and antithetic to "Kell." The blood group system that anti-*Kell* and anti-*Cellano* defined is now called *K-k*, the antigens *K* and *k* being governed by antithetic, allelic genes *K* and *k*, comparable to

M and *N*, *C* and *c*, *E* and *e*, etc. The genes, as far as studies to date go, appear to segregate independently of all other known blood group genes.

The primary purpose of the present study was to determine the distribution of the *K*-*k* genes in the white population of Manitoba through the analysis of data on 2872 unselected adults tested with both anti-*Kell* (Ram) and anti-*Cellano*: if differences existed in the gene frequencies of the racial groups making up the population they might be discovered. At the same time, by testing with anti-*A*, anti-*B* and anti-*D*, further evidence as to the linkage or non-linkage of the *A*-*B*-*O* and *D* genes with the *K*-*k* genes could be obtained.

MATERIAL

A. Blood samples

The blood specimens used were taken primarily to be tested for evidence of syphilis in men and women applying for marriage licences. The randomness of such a sample has been discussed in detail in a previous paper, Chown et al. ('49).

B. Sera

1. Anti-*K* (Ram). This serum, which was identified for us by Dr. Ruth Sanger as an anti-*Kell*, was obtained from a woman, Mrs. Ramsay, who had given birth to a baby with hydrops fetalis. The woman, who was *K*-negative, had received two transfusions from *K*-positive donors, one of whom was her husband.

2. Anti-*k* (Cellano). This serum was generously given us by Dr. Philip Levine of Ortho Research Foundation. It is some of the serum he and his associates reported in 1949.

3. Anti-*A* and anti-*B*. These were prepared from donors with high titre, high avidity sera. The titre was not increased by artificial means.

4. Anti-*D*. A single, high titre, saline-active serum was used.

METHODS

The slanted capillary method of Chown and Lewis ('51) was used for the anti-K (Ram), anti-k (Cellano) and anti-D sera. The open-well slide technique was used with the anti-A and anti-B sera.

RESULTS

Reactions

The reactions of the whole set of blood samples to anti-K (Ram) and anti-k (Cellano) were:

REACTION	NUMBER	PHENOTYPE	PERCENTAGE
$K+k-$	7	K	0.2437
$K+k+$	191	Kk	6.6504
$K-k+$	2674	k	93.1059

Gene frequencies

In accordance with the current opinion that the *Kell* reactions are due to two allelic genes, K and k, we have calculated gene frequencies by means of the formula used by Wiener and Vaisberg ('31) for genes M and N. The calculations are:

$$\text{gene } K = \text{frequency of phenotype } K + \frac{\text{frequency of phenotype } Kk}{2}$$

$$= 0.002437 + \frac{0.066504}{2} = 0.035689$$

$$\text{gene } k = \text{frequency of phenotype } k + \frac{\text{frequency of phenotype } Kk}{2}$$

$$= 0.931059 + \frac{0.066504}{2} = 0.964311$$

With the above frequencies the expected genotype frequencies are:

$$\text{Expected } KK = 0.035689^2 = 0.001274$$
$$\text{Expected } Kk = 2 \times 0.035689 \times 0.964311 = 0.068830$$
$$\text{Expected } kk = 0.964311^2 = 0.929896$$

The absolute numbers, expected and observed in the sample of 2872 are:

			EXPECTED	OBSERVED
KK	0.001274 × 2872	=	3.66	7
Kk	0.068830 × 2872	=	197.68	191
kk	0.929896 × 2872	=	2670.66	2674
			2872.00	2872

The direct calculation of chi-square for goodness of fit of the observed and expected values is:

GENOTYPES	OBSERVED (O)	EXPECTED (E)	(O – E)	O – E)^2	(O – E)^2/E
KK	7	3.66	+ 3.34	11.1556	3.048
Kk	191	197.68	— 6.68	44.6224	0.226
kk	2674	2670.66	+ 3.34	11.1556	0.004
	2872	2872.00		χ^2 =	3.278

This detailed method of calculation shows that the greater part of the total chi-square of 3.278 comes from the difference between the small numbers of 7 *KK* observed and 3.66 expected. It would be desirable to obtain more data in order to have adequate observed and expected frequencies of the *KK* genotype. However, in spite of the discrepancy in the *KK* genotype class in the present study, the total chi-square of 3.278 for one degree of freedom corresponds to a probability between .01 and .05. The deviation from expectation is therefore not excessive, but yet great enough to warrant further testing of the hypothesis of two allelic genes. This will be the subject of further study.

Since this study was completed Mourant ('54) has published data on two other studies of Whites (British), one by Ikin, Kopeć, Mourant, Parkin and Walby, the other by Parkin, in which both anti-*K* and anti-*k* were used. The agreement between expected and observed is even closer than in the present study: χ^2 1.544 and 0.0133 respectively. These two studies show no difference of statistical significance in gene frequencies from the study here reported.

Homogeneity of $K+$ and $K-$ in the racial groups

There were 10 racial groups each containing 59 or more individuals. Their reactions $K+$ and $K-$ and the percentage frequency of $K+$ are shown in table 1.

As shown by the χ^2 test for homogeneity the differences between the racial groups do not appear to be statistically significant: we should expect them to differ as much, or more, by chance in one or two of 10 similar tests of random samples of 2581 individuals.

TABLE 1

Reactions $K+$ and $K-$ and percentage $K+$ in the racial groups

RACIAL GROUP	$K+$	$K-$	TOTAL	% $K+$
Hebrew	9	71	80	11.25
Polish	18	182	200	9.00
Dutch	14	144	158	8.86
English	47	508	555	8.47
Irish	22	267	289	7.61
Icelandic	4	55	59	6.78
German	14	210	224	6.25
Scottish	21	357	378	5.56
Ukrainian	18	374	392	4.59
French	11	235	246	4.47
Total	178	2403	2581	

χ^2 for homogeneity = 14.1148; d.f. = 9; $0.20 > P > 0.10$.

This question was further examined by 2 × 2 comparisons of the racial groups, as set out in table 2.

In 45 comparisons we would expect two or three to yield, by chance, χ^2 values of 3.84 or higher. There were 5 such values, namely:

Ukrainian vs Hebrew	5.46
Ukrainian vs English	5.40
Ukrainian vs Polish	4.51
French vs Hebrew	4.82
French vs English	4.05

Neither analysis makes the existence of differences certain, but both suggest the desirability of extending the investigation to larger numbers.

TABLE 2

χ^2 values for tests of homogeneity of pairs of racial groups with respect to the proportion of the two phenotypes $K+$ and $K-$

	FRENCH	UKRAINIAN	SCOTTISH	GERMAN	ICELANDIC	IRISH	ENGLISH	DUTCH	POLISH	HEBREW
Hebrew	4.82	5.46	3.52	2.11	0.80	1.13	0.67	0.35	0.33	. . .
Polish	3.72	4.51	2.47	1.15	0.29	0.30	0.05	0.002	. . .	
Dutch	3.19	3.75	1.99	0.93	0.24	0.21	0.10	. . .		
English	4.05	5.40	2.82	1.09	0.20	0.19	. . .			
Irish	2.27	2.75	1.15	0.36	0.05	. . .				
Icelandic	0.54	0.53	0.14	0.02	. . .					
German	0.74	0.79	0.12	. . .						
Scottish	0.36	0.37	. . .							
Ukrainian	0.005	. . .								
French	. . .									

Independence of K-k from A-B-O and D

The reactions $K+$ and $K-$ in relation to the blood groups O, A, B and AB, and to the Rh groups $D+$ and $D-$, are set out in tables 3 and 4. Absence of association of K-k with A-B-O and D appears well established from the data.

TABLE 3

Distribution of 2872 whites with respect to A-B-O and Kell

	$K+$	$K-$	
O	79	1120	1199
A	85	1088	1173
B	25	340	365
AB	9	126	135
	198	2674	2872

$\chi^2 = 0.4128$; d.f. $= 3$; P $= 0.90$.

TABLE 4

Distribution of 2872 whites with respect to D and Kell

	$K+$	$K-$	
$D+$	165	2219	2384
$D-$	33	455	488
	198	2674	2872

$\chi^2 = 0.01592$; d.f. $= 1$; P $= 0.90$.

SUMMARY

Twenty-eight hundred and seventy-two random samples of blood from white adults in Manitoba, Canada, were tested with anti-K (Ram) and anti-k (Cellano). The results were $K+k-$ 7; $K+k+$ 191; $K-k+$ 2674. The calculated gene frequencies were $K = 0.0357$; $k = 0.9643$.

The reactions K + and K — in 10 racial groups of 59 or more individuals within this population sample were examined for homogeneity. The value $0.20 > P > 0.10$ for the comparison suggests no marked heterogeneity. Among 45 2×2 comparisons between these racial groups 5 had a χ^2 value greater than 3.84, the value for a probability of .05.

The samples were also tested with anti-*A*, anti-*B* and anti-*D* (Rh_0) and the data examined for evidence of linkage of the *A-B-O* and *D* genes with the K-k genes. No evidence of such linkage was found.

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BODY TYPE OF FINNISH CHAMPION LUMBERJACKS

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FIVE FIGURES

The work of a lumberjack requires the highest caloric expenditure of all occupations. Large groups of muscles are active, and the work is sufficiently variable, so that a high rate of caloric expenditure can be kept up with relatively short pauses. A lumberjack has to combine endurance with considerable muscular strength.

In Finland, about 200,000 men of a total population of 4,000,000 do lumber work every winter. Working competitions are arranged among the lumberjacks on three levels: district, county and national competitions. The participants of the national finals, who have qualified for them through double trials, thus form a highly selected group, as far as their working capacity is concerned. It is reasonable to assume, that if there are any typological characteristics favorable to this kind of work, these men can be expected to show them. Moreover, the competition affords another possibility to study the interrelations of body type and working achievement by correlating the work output in the competition with various body measures.

Similar studies have been previously made on athletes representing various sports, but the writers are not aware of any published studies made on the participants of working competitions, except for a previous report on some body measures of champion lumberjacks by Karvonen and Kunnas ('47). The present study includes the results of the earlier work, plus additional material with a more comprehensive set of measurements.

MATERIAL AND METHODS

The material consists of two groups of champion lumberjacks. One group, the 31 participants in the 1945 championships, was selected with the aid of double trials from among 3,014 lumberjacks taking part in district competitions, and the other group, the 40 participants in the 1951 championships, was similarly selected from a primary group of 995 lumberjacks. Seven of the participants of the latter competition had qualified to the finals of 1945; for them, the measurements taken in connection with the 1951 competition only are considered. The participants of the national finals may be considered as equivalent to top-class athletes, which is also shown by the fact that the same men tend to keep their status among the champions over a long period of time.

The following measurements were made, according to directions given by Martin ('28). The number refers to Martin's directions, and the year or years in brackets after the measure indicate, whether the same measurement was taken on both occasions.

1. stature (1945, 1951)
71. body weight (1945, 1951)
23a. trunk length (1951)
45a. arm length (1945, 1951)
49. right hand length (1951)
52. right hand breadth (1951)
35. shoulder breadth (1945, 1951)
36. transverse chest breadth (1945, 1951)
37. sagittal chest depth (1945, 1951)
40. hip width (1951)
53. leg length (1951)
65. right upper arm maximum circumference (1945, 1951)
66. right under arm maximum circumference (1945)
68. right thigh circumference (1951)

From the above measures the following indices were calculated:

Strömgren's index: using a nomogram (Enke, '40), where stature, chest breadth and chest depth form the basis of the index;

$$\text{hand index} = \frac{\text{hand breath} \times 100}{\text{hand length}};$$

$$\text{hand-arm index} = \frac{\text{hand length} \times 100}{\text{arm length}};$$

$$\text{leg index} = \frac{\text{arm length} \times 100}{\text{leg length}}.$$

Somatotyping was made by Dr. Albert Damon and Miss Marja Wallasvaara, College of Physicians and Surgeons, Columbia University, New York, who have got their training under Dr. Sheldon's personal guidance, using the technique of Sheldon ('40), from photographs taken on nude subjects from three directions (front, back, side, see figs. 3–5), and using Sheldon's table 23, which indicates the classification of somatotypes according to the ratio height/cube root of weight.

Mathematical treatment. The mean and the standard deviation of each measure is given for the whole material. These values are compared with measures reported on other groups using the t-test. Moreover, in order to relate the performance to the body type, a correlation coefficient was calculated between each measure and the work output during the competition, as expressed as cubic meters of wood cut. In order to make the output figures comparable, the results were corrected as to the type of trees, undergrowth, terrain etc. by a body of experts in forestry. As many of the body measures are positively correlated with the stature, correlation of these with the work output is influenced by general body size. One way to eliminate the effect of body length in this respect is to use measures expressed as a percentage of the length. Though frequently used, this method is inefficient statistically. Therefore, the method of partial correlation analysis (Fisher, '50) was used.

RESULTS

The results are given in the form of tables. Table 1 shows the absolute body measures of the lumberjacks, together with

TABLE 1

Mean absolute body measures of champion lumberjacks, as compared with the mean measures of Finnish champion throwers and long distance runners (Telkkä et al., '51), and with Finnish mean values (Pesonen, unpublished). ± *Standard deviation; n = number of subjects.*

MEASURE	LUMBERJACKS	THROWERS n = 46	RUNNERS n = 51	FINNISH MEAN VALUES n > 7000
Stature, cm	173.7 ± 5.73 n = 64	180.7 ± 5.71[1]	172.0 ± 6.22	168.9
Body weight, kg	72.7 ± 6.68 n = 64	85.7	64.5	
Trunk length, cm	56.0 ± 2.11 n = 40	55.5 ± 2.69	52.2 ± 2.58[1]	52.11
Arm length, cm	80.8 ± 3.39 n = 64	79.8 ± 3.94	76.8 ± 4.13[1]	76.3
Hand length, cm	19.0 ± 0.87 n = 40			
Hand breadth, cm	9.1 ± 0.37 n = 40			
Shoulder breadth, cm	39.1 ± 1.70 n = 64	40.6 ± 1.87[1]	37.7 ± 1.90[1]	38.3
Transverse chest breadth, cm	30.2 ± 1.57 n = 64	32.1 ± 1.99[1]	29.2 ± 1.82[2]	28.9
Sagittal chest depth, cm	22.3 ± 1.23 n = 64	22.3 ± 1.67	20.5 ± 1.38[1]	20.3
Hip width, cm	29.3 ± 1.23 n = 40	31.0 ± 1.72[1]	28.8 ± 1.67	29.5
Leg length, cm	91.0 ± 4.07 n = 40	96.3 ± 4.43[1]	92.8 ± 4.96	89.4
Upper arm circumference, cm	29.3 ± 1.74 n = 64	31.3	25.9	
Under arm circumference, cm	27.6 ± 1.00 n = 31			
Thigh circumference, cm	51.3 ± 3.19 n = 40	58.3	50.2	

[1] Difference from the corresponding value of lumberjacks is significant at the level $p < 0.001$.

[2] Difference from the corresponding value of lumberjacks is significant at the level $p < 0.01$.

a comparison with those of Finnish champion throwers and long distance runners (Telkkä et al., '51). These two groups were chosen for comparison, since the type of the lumberjacks' work has certain similarities to both of them; the requirement of endurance is common with long distance running, and the use of the axe requires the same muscles and similar movements as the throwing sports. Further, mean values for the adult Finnish male population (Pesonen, unpublished) are also shown.

In several of the measures, the mean of the lumberjacks was between those of throwers and long distance runners; these measures were stature, body weight, shoulder breadth, transverse chest breadth, hip width, upper arm circumference, and thigh circumference. The sagittal chest depth was the same as that of the throwers, both being significantly larger than the corresponding measure of runners. The mean values of trunk length and arm length exceeded the corresponding values of throwers, but the difference is significantly only as compared with the runners. On the other hand, leg length was on average shorter than that of both sport groups, the difference being significant only with the throwers. As compared with the mean values of adult male Finns, the lumberjacks were larger, except for hip width.

The corresponding relative measures as a percentage of stature were similarly compared. Hip width, upper arm circumference and thigh circumference were again between the corresponding measures of throwers and runners. Relative trunk length and relative arm length were significantly greater than in each sport group ($p < 0.001$), and relative leg length showed the opposite relationship, although the difference was not statistically significant. Relative shoulder breadth was the same as that of throwers. A comparison with the mean values of Finns shows that the lumberjacks have a relatively long trunk and long arms, and narrow hips. On the whole, however, the relative measures showed fewer statiscally significant differences than the absolute measures, and no regular pattern was observed.

Table 2 lists the various body indices, affording a comparison both with the two groups of athletes and with material analysed by Jalavisto ('46). The lumberjacks have characteristically broad and short hands, and the length of the arms as compared with the legs becomes clearly evident. The Strömgren index is a measure of the position of a person along the axis "pycnic-leptosome" according to the terminology of Kretschmer's typology. Jalavisto has shown that for the Finnish male population — 0.40 is the mean value (the same mean value has been reported also from other European countries); values more positive represent cyclotym preponderance, and vice versa. The lumberjacks were grouped more on the cyclotym side, although no extremes were found. The distribution of the Strömgren indices is shown in the frequency distribution diagram (fig. 1).

TABLE 2

Various mean body indices of champion lumberjacks, as compared with the mean indices of Finnish champion throwers and long distance runners (Telkkä et al., '51), and with Finnish mean values (Pesonen, unpublished; Jalavisto, '51). ± Standard deviation; n = number of subjects.

INDEX	LUMBERJACKS	THROWERS n = 46	RUNNERS n = 51	FINNISH MEAN VALUE n > 7000
$\frac{\text{Hand breadth}}{\text{Hand length}} \times 100$	48.2 ± 1.99[1] n = 40	45.0 ± 3.78	44.6 ± 3.07	
$\frac{\text{Hand length}}{\text{Arm length}} \times 100$	23.5 ± 0.86[1] n = 40	25.4 ± 1.31	25.0 ± 1.26	
$\frac{\text{Arm length}}{\text{Leg length}} \times 100$	88.8 ± 2.66[1] n = 40	82.9 ± 3.71	83.2 ± 3.43	85.3
Strömgren's index	— 0.12 ± 0.30 n = 64			— 0.40

[1] The difference of this value from the corresponding values of both throwers and runners is highly significant ($p < 0.001$).

Another approach to typology is the Sheldon-Stevens-Tucker classification (Sheldon, '40). The word "phenotype" is used instead of the more commonly known "somatotype" because "somatotyping" implies a knowledge of the weight history of the subject (Sheldon, personal communication); in this particular group, however, the phenotypes are probably closely identical with the somatotypes.

Mesomorphy is the predominant element. The distribution of the typings is shown diagrammatically in figure 2, which clearly illustrates the characteristics of the group. Particularly endomorphy is absent, whereas a slight tendency to ectomorphy can be observed.

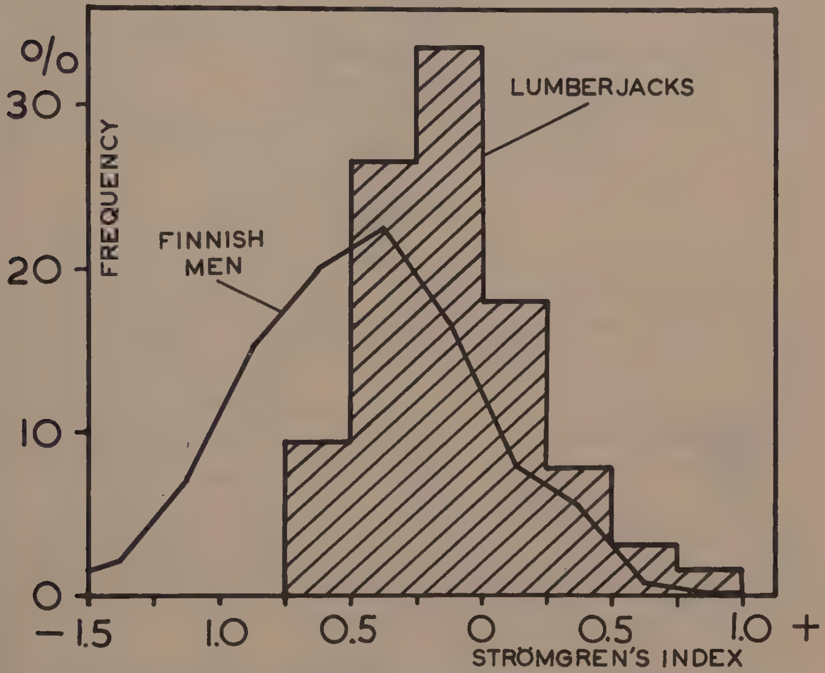

Fig. 1 Strömgren's index: the variation polygon of the champion lumberjacks of 1945 and 1951, with the frequency curve representing the whole male population (Jalavisto, '46).

Figures 3–5 show, as examples, the photographs of the three winners.

The statistically significant interrelations of body measures and work output are shown in columns 1 and 2 of table 3.

Significant correlations were shown by the absolute and relative size of the hand, body weight, leg length, stature and hip width.

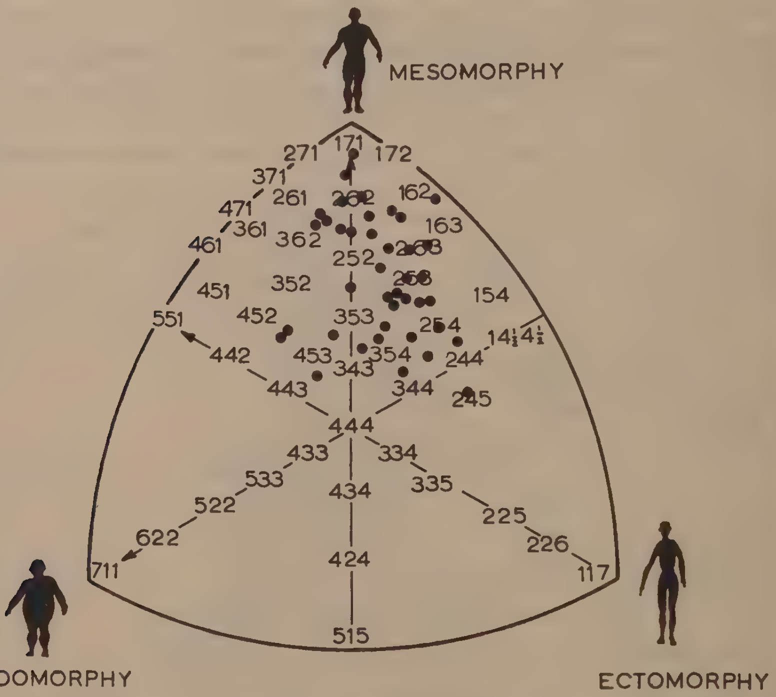

Fig. 2 Distribution of phenotypic impressions of the champion lumberjacks of 1951.

TABLE 3

Correlation analysis of significant correlations between anthropometric measures and performance

MEASURE	CORRELATION WITH PERFORMANCE		CORRELATION WITH STATURE		PARTIAL CORRELATION WITH PERFORMANCE [1]	
	Coefficient	p	Coefficient	p	Coefficient	p
Stature	0.418	< 0.025				
Hand length	0.569	< 0.001	0.760	< 0.001	0.42	< 0.05
Hand breadth	0.505	< 0.005	0.697	< 0.001	0.32	> 0.05
Body weight	0.451	< 0.010	0.753	< 0.001	0.22	> 0.1
Leg length	0.437	< 0.025	0.856	< 0.001	0.16	> 0.5
Hand-arm index	0.384	< 0.05	0.124	> 0.5	0.37	< 0.05

[1] The effect of stature is eliminated.

An attempt was made to find out, whether the statistically significant correlations really indicate a dependence of the work output on the particular measure, or whether all the positive correlations are only indicators of body size, the primary correlation being between body size and work output. For this purpose, each measure was correlated with stature (columns 3 and 4, table 3), and the partial correlation coefficient between each measure and work output was calculated, excluding the effect of stature. The results are shown in columns 5 and 6 of table 3. Of these measures, hand length and hand-arm index were the only ones with a significant partial correlation coefficient to the performance.

DISCUSSION

Champion lumberjacks as a group can be defined as relatively tall men, with long trunk and long arms, but with relatively short legs. The hand is large, but the hip relatively narrow. The musculature is well developed but not particularly hypertrophic. However, the group is by no means uniform. Wide variations occur and a considerable proportion of the competitors were even below the corresponding mean measures of the Finnish adult male population.

According to Sheldon's classification the general body type of the lumberjacks shows mesomorphic (or athletic) predominance, with a slight tendency to ectomorphic (or leptosomic) type. The extreme ectomorphs, however, and particularly the extreme endomorphs are excluded.

The Strömgren index, however, gives a slightly different picture. The competitors are grouped distinctly on the side of the cyclotyms. The classification according to the Strömgren index fails to discriminate between athletic and cyclotym, and it is quite obvious that an increase in the athletic component tends to move the person's index towards cyclotym values. The size of the thorax determines the numerical value of the index, and it is well known that intense training, age, and the development of emphysema cause marked changes in the size of the thorax. To illustrate the uselessness of the

Strömgren index on athletes, it may be mentioned that the index of the winner of the competition of 1951 had changed from — 0.44 to + 0.77 in the course of six years, although his constitution, as assessed by other means, had not essentially changed. The Strömgren index, though it may be useful in some specific instances, must therefore be regarded as a doubtful indicator as far as the constitutional type is concerned. Kretschmer ('31) himself has repeatedly pointed out that typological diagnosis must be based on as many criteria as possible.

The correlations between various body measures and performance within the champion group showed that the work output was positively correlated with general body size and the size of hand. However, we like to emphasize that these correlation coefficients were relatively low. The highest observed correlation coefficient (+ 0.569) indicates that most of the original variance still remains unexplained by the correlation! Obviously other factors than those revealed by the anthropometric measurements are determinants of success in these competitions. Training and certain psychological characteristics may be much more closely correlated with performance than slight variations in the bodily "instrument" with which the central nervous system realizes its aims. Nevertheless, that these variations are not entirely without effect, is shown by the results of the present study.

As a group, the champion lumberjacks are in many respects intermediate to the tall, muscular throwers and to the smaller and skinnier long-distance runners. The relatively long arms and trunk and short legs make them, however, a "type" of their own. As compared with weight lifters (Tappen, '50), the lumberjacks do not reach the same extreme mesomorphy, and they also show more tendency to ectomorphy than weight lifters. Neither can the group of lumberjacks be identified with any of the groups of sportsmen somatotyped by Cureton ('51).

SUMMARY

An anthropometric and typological study was made on the participants of two finals of the Finnish national woodcutting competitions.

The competitors were tall men with long trunk and long arms but with short legs. The hand is large and the hip narrow. According to Sheldon's typology the mesomorphic element is strongly predominant. Strömgren's index, whose applicability on athletes is criticized, excluded the leptosome type.

In many respects the anthropological measures of lumberjacks are intermediate to those of champion throwers and long-distance runners, respectively.

Within the group of the competitors, hand length, hand breadth, body weight, leg length, stature and hand-arm index showed a significant posive correlation to work output. Closer analysis revealed that a part of this correlation is due to general body size; excluding the effect of stature, the work output shows a significant partial correlation with hand length and hand-arm index only.

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PLATE 1

EXPLANATION OF FIGURES

3–11 Photographs of three winning lumberjacks of the 1951 competition

3 Winner, phenotype 2½62.

4 Second place, phenotype 263.

5 Third place, phenotype 1½6½3.

VIKING FUND MEDALIST FOR 1954

The American Association of Physical Anthropologists, on the unanimous recommendation of its Awards Committee, has selected Dr. William White Howells of Harvard University to receive the Viking Fund Medal and Award in hysical Anthropology for 1954.

Doctor Howells was born in New York City. Following raduation from St. Paul's School, at Concord, New Hampire, in 1926, he entered Harvard, from which he successively ceived the S.B. degree in 1930, the A.M. in 1931, and the h.D. in Anthropology in 1934.

After spending several years as research associate at the American Museum of Natural History in New York, Doctor Howells joined the faculty of the University of Wisconsin as Assistant Professor of Anthropology in 1939. In 1948 he became Professor, and, in 1953, Chairman of the Department of Sociology and Anthropology. Only this past fall he was called back to Harvard to fill the post left vacant by the untimely death of his former teacher, E. A. Hooton.

I asked Bill Howells how he happened to become interested in physical anthropology. In characteristic manner, he replied, "I was interested in physical anthropology by Hooton. This is about the long and short of it." Like Hooton's other utstanding students, Howells reflects the catholicity of the aster. For, although actually a physical anthropologist, he as an extraordinarily broad range of interests and knowledge, both anthropological and otherwise — all of which makes him an ideal liaison man between physical anthropology and other areas of anthropology. His success in this respect is attested to by the many offices that he has held in the American Anthropological Association, culminating in his election to the presidency in 1951.

Viking Fund Medalist for 1954

William White Howells

Moreover, Bill Howells is certainly one of the most literate and scholarly of all anthropologists, physical or otherwise. His three books, ''Mankind So Far'' (1944), ''The Heathens'' (1948), and ''Back of History,'' the last-named having been published less than a year ago, are rare examples of a happy blending of scientific accuracy and literary skill. ''Mankind So Far'' had a great and beneficent influence on anthropological teaching, and ''Back of History'' threatens to do likewise. Although environment undoubtedly played a considerable part in the phenotypic development of Bill Howells' outstanding literary talents, it is not difficult to find its genotypic basis. For his paternal granfather was the eminent novelist, William Dean Howells.

In addition to his three books, Doctor Howells is the author of over 30 technical monographs and articles. His earlier publications deal largely with racial studies, together with a strong, continuing interest in fossil man. In recent years he has turned, with notable success, to a study of physical differentiation from the standpoint of family line and factor analysis.

This by no means embraces all of Bill Howells' activities as a physical anthropologist. He has long been one of the most active and influential members of the American Association of Physical Anthropologists, serving as Secretary-Treasurer from 1939 to 1943 and as Editor of the American Journal of Physical Anthropology from 1949 through 1954. On his success as an editor, and on the pre-eminent position in which he left the Journal, I need not dwell — these are well known.

I have spoken to you of William White Howells, the scientist and scholar. Those who are privileged to be his friends recognize that the same sterling qualities are characteristic of Bill Howells, the man. Therein lies the reason for his great influence on American anthropology today.

In behalf of the American Association of Physical Anthropologists, it gives me great pleasure, Doctor Wenner-Gren, to present Dr. William White Howells for the Viking Fund

Medal and Award for 1954 in recognition of his studies on the phenomena of physical differentiation in man, and for his literary and editorial contributions to physical anthropology in general.

WILLIAM L. STRAUS, JR.
President

BRIEF COMMUNICATIONS

THE INCIDENCE OF THE KELL FACTOR IN SAO PAULO, BRAZIL

C. S. LACAZ, D. O. PINTO, S. O. BORGES, O. MELLONE AND O. YAHN
Department of Microbiology and Immunology, and Blood Bank of the Hospital das Clínicas of the Faculdade de Medicina da Universidade de São Paulo

The distribution of the Kell factor has been studied in several countries, especially when the participation of this agglutinogen was demonstrated in cases of post-transfusional hemolytic accidents, as well as in the etiopathogeny of hemolytic disease of the newborn.

MATERIALS AND METHOD

Samples of oxalated blood of 521 donors were used and the Kell factor was determined with blocking serum, on the slide. The serum used was obtained from a case of immunization to the Kell factor, studied by Ottensooser and Taunay ('54), diluted to 1:6 in 20 g % equine albumin.

As a rule, the positive reactions were very clear; cases of doubtful agglutination, which asked for a repetition of the experiment, were rare.

RESULTS

The following results were obtained (table 1 and 2).

In São Paulo, Ottensooser and Taunay ('54), in 462 samples of blood (246 determined by the authors and 216 determined previously by Mellone, '54) obtained 39 positive results; to these statistics we can add those of Ottensooser et al. ('53) referring to 182 experiments with 14 positive cases. Adding these results to ours, we obtained a total of 1.165 samples, with the following results(table 2).

TABLE 1

Distribution of the K-k blood groups

NUMBER EXAMINED	KELL		GENE FREQUENCIES	
	Positive	Negative	K	k
521	40 7.67%	481 92.33%	0.0392	0.9608

TABLE 2

Total results in São Paulo

NUMBER EXAMINED	KELL		GENE FREQUENCIES	
	Positive	Negative	K	k
1165	93 7.98%	1072 92.02%	0.041	0.959

SUMMARY

The authors, on determining the incidence of the Kell factor in São Paulo, Brazil, in 521 samples of blood, registered a positivity of 7.67%, with a gene frequency of: K = 0.0392 and k = 0.9608.

These determinations, added to those made by Ottensooser and Taunay ('54) and Ottensooser et al. ('53) in Brazil, give a total of 1.165 with the following results:

Kell positive = 7.98%
Kell negative = 92.02%

$$\text{Gene Frequency}\begin{cases} K = 0.041 \\ k = 0.959 \end{cases}$$

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MORE ON THE EDUCATION OF THE PHYSICAL ANTHROPOLOGIST

(FROM THE VIEWPOINT OF GENERAL ANTHROPOLOGY)

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In the December 1954 issue of the American Journal of Physical Anthropology, Garn puts forward several suggestions for the improvement of graduate training in physical anthropology. His main proposal is that students specializing in physical anthropology augment their knowledge of basic biology, and with this point one can have no argument. Yet one wonders what is to become of the ''anthropological'' in physical anthropology if a major portion of the graduate student's time is spent, not in learing about physical anthropology, but in acquiring the techniques for applied studies. Under such circumstances the student may come out no better prepared to comprehend the essentials of human development than previously. Medical, dental and genetic research organizations no less than those concerned with human biology are becoming increasingly interested in bio-anthropology because they realize more than they did in the past how greatly the cultural and biological factors, which are the anthropologist's province in the first place, complicate their problems. If a student's main purpose is to contribute to research in physiology, endocrinology or genetics, some acquaintance with physical anthropology may be helpful to him, but he should no doubt be encouraged to focus his graduate training in the area in which he wants to work. Fortunately appreciation of the potential contribution of anthropology to education in medicine and the biological sciences has reached the point where students of these subjects will get recognition as well as satisfaction from acquiring some knowledge of physical anthropology.

These advantages are not diminished by retaining the connection which exists between physical and cultural anthropology. On the contrary, they are enhanced by the physical anthropologist's familiarity with both the biological and the social sciences. To the general anthropologist, physical anthropology has more to offer than a formal introduction to the family tree of unpronounceable, unspellable names of forbears. The facts of the essential biological unity of mankind and the importance of human evolution as prerequisites for cultural development seem, to me at least, more significant to the general anthropologist than are questions concerning the excretion of 17-ketosteroids, or the microchemistry of human blood groups. This is not to say that the specialist should not be familar with those of the techniques which Garn mentions that apply to his problems, but only that the sole justification for training such a specialist as a physical anthropologist is the relevance of anthropology to these problems. Each graduate student must be left to decide (with his professors) which of these techniques are most likely to be useful to him in his research. Obviously, to become a master of all the new techniques would take too much time: the field is now so broad within itself that today no physical anthropologist is likely to attempt research in all of its 5 or 6 major sub-areas.

Garn is worried that "few physical anthropologists have managed to employ investigative techniques or methods of analysis not already familiar to them by the end of their graduate careers, . . ." If this were the case he would not now be able to point with pride to the diversity of fields into which traditionally trained physical anthropologists have gravitated in recent years, nor to the fact that the fields of research encompass far more than mere anthropometry. Obviously, physical anthropologists have learned to utilize and to develop new techniques as their research interests have grown.

Furthermore, to argue that the mastery of techniques can be achieved only by an expansion of the training period is unduly restrictive and unrealistic. Of 32 physical anthropologists listed recently only 8 took 5 years or less between their bachelor's and Ph.D. degrees, 8 took 6 or 7 years, 8 took 8 to 10 years, and 8 took 11 or more years. While some of these individuals interrupted their studies, relatively few students today are financially able to prolong their years of graduate study beyond those at present required. Garn says that there are few who complete their training with "the traditional 8 full courses . . ." For the Harvard graduates I might explain that in most other graduate schools (whether on a semester or a quarter system) a minimum of 60 credits (i.e., 20 half-year courses) are required before a student is considered to have fulfilled his graduate residence for a Ph.D., and at some universities as many as 27 such courses (*i.e.,* 90 credits or three years of residence) are now required. Yet, obviously, the counting of courses alone is not sufficient to decide when a student is well enough trained to emerge at full-term with a clean-cut umbilical cord ready to enter "Academia Groves" as a mature scholar. Whatever the justification for limiting the number of journeyman plumbers by extending the period of apprenticeship, there is none in physical anthropology. We have a scientific purpose which biologists appreciate; and we should be willing to let go of our students when they have grasped the relation of our discipline to others, have selected an avenue of research and acquired the requisite competency for it as shown by their production of an acceptable thesis.

It is to be hoped that the new Ph.D. in anthropology will leave his graduate institution equipped with an understanding of and a committment to the "anthropological point of view" — that bond which makes it possible for anthropologists to communicate with each other, however remote their fields of specialization may be. He should also emerge with a clear understanding of the role which physical anthropology plays in general anthropology — so clear an awareness that he will be able to enter programs in medical schools, dental schools, the quartermaster corps or the Bronx Zoo and not become so completely engulfed in specialized research as to lose sight of man, the bio-cultural animal. Obviously, he will need techniques which will be useful to him in his research, but he will also need to be sufficiently flexible to be able first to recognize what techniques are needed and, secondly, to know where to seek help in the development of new techniques. Above all, he must know which factors in the problem he confronts have possible relevance to the various questions of human biology. His success depends on what he considers worth investigating about these questions. And his insight — no less important than his mastery of techniques — depends on how he is trained.

Garn says, "Once anthropometry was *the* technique of physical anthropology, . . ." Actually functional anatomy has always been more important. Boas in 1899 argued for the biological relevance of measurements and other techniques in physical anthropology, a view more recently again emphasized by Washburn ('52) among others. From a sample of the formal training in physical anthropology which I have recently had reason to survey, I gather that evolutionary theory, human morphology and human genetics are the central areas of the field of knowledge today. Others may think differently. For physical anthropologists in general it is a healthy sign that they have not dug themselves in so deeply as to be incapable of extricating themselves and taking new directions.

By all means, the training offered in graduate departments should change with the times — with this no one can disagree. The student should be given an opportunity to explore problems and develop skills related to new interests or new professional opportunities. The only training all will need concerns the core of knowledge about human evolution and variation. Beyond this, each department will develop in terms of the interests and capabilities of its own staff and students, perhaps also with an eye on other facilities that may be available in the university. Homogeneity among physical anthropologists is as much to be feared as is homogenized thought in other sciences.

One need not take too seriously the forecasts of external influences on scientific teaching in general and that of physical anthropology in particular which threaten the integrity of research, to be aware that there are pressures, both from business and from government, which — unless counterbalanced by other pressures — might divert the needed professional training into channels of an unduly narrow and incautious application of existing knowledge. We should never forget that physical anthropology, in spite of its strides in the last half century or so, is a young science, and that its major task still is that of adding to the body of knowledge — not that of building man, as one writer has it, into the machine as an integral part of it.

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REVIEWS

STAROSLOVENSKA NEKROPOLA U PTUJU. By Franjo Ivanicek. (The Old Slavic Necropolis at Ptuj.) Slovenska Akademija Znanosti in Umetnosti v Ljubljani (Slovenian Academy of Sciences and Arts), Dela 5, Ljubljana, pp. 101, sixty-one orthograms, seventy tables. 1951.

Ptuj is a town almost due north of Zagreb (about 70 km in a straight line), on the Drava River, between Maribor and Čakovec; it is in Slovenia, part of modern Yugoslavia. This study analyzes the skeletal material unearthed from a Slavic necropolis in Ptuj, a necropolis dating from the 10th and 11th centuries A.D. The cemetery was probably abandoned at the time of the introduction of Christianity among these people. The skeletons studied come from a well-preserved and peaceful cemetery, accurately dated; the study is a valuable addition to our knowledge of the physical state of the Slavs in Slovenia, several centuries after the beginning of the expansion of the Slavs in general.

The book is almost entirely focussed on craniology. N was 299, of which 104 were male, 94 female, and 101 doubtful (the large number of infantile skulls swelled the class of "doubtful"). As would be expected, there were many infantile and young adult graves; only 13.5% of the male and 16.0% of the female individuals were senile (50 and over). The cemetery was evidently used for about a century (no overburying, preservation identical), and that during a peaceful time. There were no mass graves, as might have been dug after a battle; the proportion of males and females is about the same; there is a high number of males 30–50 years of age, and these would presumably have been buried elsewhere had they fallen in battle.

A few remarks of a medical nature are interesting. The level of skill of the local surgeons is indicated by the fact that broken long bones are well healed, but fractures involving the epiphyses or implying the need of traction are poorly healed. Tooth extraction seems to have been well done, as evidenced by the numerous regularly atrophied alveoli of the senile specimens. There was very little rickets, a little osteomyelitis and possibly a trace of tuberculosis. Most pathological manifestations, however, were of a rheumatic nature — probably implying ill-adapted clothing and unsuitable dwellings.

The author states that the primary purpose of the monograph is to establish the significant characteristics of the phenotype of this particular population. These characteristics fall into two categories: the sex-linked, and the racial.

In the long list of sex-linked characteristics, I shall cite only those which seem to me of some importance. The unmentioned characteristics are either necessarily correlated with those cited, or absolutely unimportant, in my opinion.

The female has a tendency towards brachycephaly, the skull of the male being on the average longer. The male exhibits mesoprosopia to leptoprosopia, whereas the female is mesoprosopic to euryprosopic. As regards the orbits, the female is more hypsiconchic than would be expected. The male is considerably more prognathous than the female. For stature, the male average is 167 cm, the female 157.

The racial groupings are given by the author as: Nordic (the principal element), Baltic, Alpine, Cro-Magnon. Insignificant percentages are: Dinaric, Mediterranean. Ptuj is a case history of the admixture of the predominantly Nordic Slavs with other racial groups during their migration from their original home.

The fact that these Slavs are in the majority Nordic agrees with current ideas concerning the northwestern and northeastern Slavs (N. Niederle, 1891; J. Czekanowski, '30). Our author, however, claims that the people of Ptuj are clearly allied with the northwestern and southern Slavs, and not with the northeastern Slavs. He states that brachycrania came from the east and northeast, in Europe. He admits that not much is known concerning the Illyrians, who were on the ground previously (the Illyrians were probably basically Nordic, but the amount of skeletal material is small: Coon, '39, pp. 182–186). He remarks that brachycrania is dominant to dolichocrania, and alludes to the larger question of the brachycephalization of Europe.

This is a large question indeed, and not to be settled by a paragraph in a review. In 1950 (esp. pp. 59 ff.) I gave a review of the situation, and I do not know of any significant publication since, which would materially change the picture. The basic difficulty, of course, is the fact that we cannot separate out the genetic elements in head form. Even from the genetically unfocussed picture we have, it cannot be said that brachycephaly is always dominant to dolichocephaly. However, in Central Europe, and specifically Yugoslavia, the skulls of more recent vintage are predominantly brachy, whereas those of the time of Ptuj are largely dolicho (with a sprinkling of brachy). This change over cannot be explained by our existing genetical evidence. I have added ('50) a further disturbing element, cultural conditioning, which can affect brachy as well as hyperbrachy heads, but is not the entire answer, either. There is no evidence, in the illustrations, of any detectable deformation of the Ptuj skulls.

One of the suggestions of our author in this respect is interesting. He opines that the actual composition of bone is different as between dolichos and brachys. This involves macroscopically visible structure, and also the amount of organic matter inherent in the bones. The brachy skulls have less organic matter, and hence tend to disintegrate more, and consequently would not be so well represented in excavation material. However this may be (and I personally doubt it), the author has gone on in later, but still unpublished work, to show considerable differences to exist in the structure of the parietal bone when specimens of various racial origins are studied. It is to be hoped that he will continue this work. (The author is now a Research Associate at Fordham University; however, I have consulted him only about factual information in preparing this review.)

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CANCER: RACE AND GEOGRAPHY. Some Etiological, Environmental, Ethnological and Statistical Aspects in Caucasoids, Mongoloids, Negroids and Mexicans. By Paul E. Steiner, pp. xiii 363, 50 tables, 73 figs. Williams & Wilkins, Baltimore. 1954.

A statistical analysis of racial and geographical differences in the frequency of cancer is presented in this book in the hope of throwing light on the genetic and environmental elements in cancer etiology.

The author anticipates correctly that such an analysis will show very large gaps in our knowledge. Yet it is hoped that this study will stimulate new research on this problem.

The data for study are 6,072 cancer cases found in 35,293 autopsies at Los Angeles County Hospital in the years between 1918 and 1947. The autopsy population was composed of 26,515 Caucasoids, 6,150 Mexicans, 2,236 Negroids, 239 Japanese, 70 Chinese, and 83 Filipinos.

The author uses the excellent procedure of comparing the Los Angeles migrants with similar migrants of each group in other countries and with the sedentes. It is undeniable that migration forms a unique mass experiment on genetic vs. environmental factors. Unfortunately it is equally undeniable (and the author, an experienced pathologist, is well aware of this handicap) that of all morbidity statistics those of cancer are the most unreliable; all too often being statistics of different levels of diagnostic progress rather than of different frequencies. In addition migrants in practically all existing statistics are not differentiated into first and second generation, a decisive difference in the case of cancerogenesis. The author's comparisons therefore yield findings which are mostly inconclusive.

Having compared migrant-sedentes samples, the author then examines ''biological differences associated with race other than frequency'' and speculates on etiology. He applies this scheme first to the total cancer frequency, then to each of the 20 most common cancers in the Los Angeles material — 91% of all cancers found there.

The Los Angeles material shows differences in age corrected total frequencies between the different ethnic groups: total cancer frequency of the Mexicans being 76%, the Negroids 84%, and the Japanese 120% of the Caucasoid group. I can not agree with the author's assumption that groups, if compared on the same age level (e.g. 100 70-year-old Mexicans vs. 100 70-year-old Caucasoids) are in other respects biologically identical with regard to cancer. To me these groups undergo a different selective process, experiencing different mortality in earlier years, and are therefore comparable only to a very limited extent.

The author's use of the ill defined expression ''race'' for the ethnic groups he discusses is a source of continuous and profound confusion throughout the book. Instead of flippantly refering to the ''wisdom of the newsboy,'' the author might preferably have given some thought to the problem and the genetic requirements of the term ''race.'' The Mexicans, one of his three ''races,'' (the Mongoloids are not numerous enough for comparative treatment) are admittedly un-definable as to race. The Los Angeles ''Negroids'' are actually considerably mixed; yet he seems unaware of the fact that differences between them and Africans are possibly explained on these grounds. His confusion in this field leads him to use Algerian statistics for proof of bone sarcoma frequency in Negroids. The same conceptual unsoundness leads him to write such inconsistent things as ''The apparent increase of this tumor in Negroid emigrants as contrasted with sedentes, would suggest that, in this race at least, a determining racial influence is environmental in nature (p. 196), and, ''Race might also predispose to skin cancer, not because of genetical predisposition but because of associated cultural, economic, social and special environmental factors'' (p. 222). The quotations show uncertainty as to what he means by race. In general, the author concludes that frequency differences between populations are due to environmental rather than genetic causes.

However presented and whatever their meaning, the book is full of data which in their very uniqueness are most stimulating. For instance stomach and gallbladder cancer, low in Africans, apparently increase in frequency in population after migration to the West Indies or U.S.A., with liver cancer decreasing. In contrast, liver cancer is equally frequent amongst East Asiatics at home and abroad. Skin cancer frequency is low in the Afro-American, but not in the Africans. Nasopharyngeal cancer occurs in the same proportions among Chinese in China and in Cuba and U.S.A. Pulmonary and laryngeal cancer in Mexican women at Los Angeles is very high, twice that of Caucasoid women, and gallbladder cancer is even three times as frequent in Los Angeles Mexican women while they have only half of the amount of breast cancer of Caucasoid females. Caucasoids show the highest rates of cancer of the large intestine in spite of greater frequency of inflammatory lesions of this region in non-Caucasoids.

In spite of its methodological shortcomings, this is an important book and the author has shown considerable courage, ingenuity and extraordinary industry in composing it. This is the first systematic attempt to survey the geographical and ethnic distribution of cancer in 40 years. In such a difficult field as cancer, where so little is actually known in spite of mountains of literature, the presentation of inadequate data is an accomplishment. It might lead to significant discoveries.

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CRECIMIENTO. METODOS DE ESTUDIO. By Manuel Suarez, pp. 260. Publicaciones de Revista Espanola De Pediatria VIII, Zaragoza. 1953.

Within the paper covers of the book is found a well organized review of the major works on growth and development, including many of European origin previously unknown to this reviewer. The emphasis of the book, as the title implies, is on methods of growth study. The material is a slight modification of a presentation on the same subject originally made in 1952 by the author at the Spanish Pediatric Congress in Barcelona. As well as giving a review of growth studies, 4 subjects of original study by the author and his collaborators are included: (1) a new graphic method for the representation of growth; (2) a correlation between ''bone age'' as determined radiographically and the level of alkaline phosphatase in the blood; (3) a correlation of muscle ''area'' on radiographs and creatinine excretion; and (4) the radiographic determination of thickness of the panniculus adiposa over the anterior abdominal wall as an index of nutritional status.

The contents are divided into separate chapters which can be read independently. Subheadings of chapters are readily found by reference to the table of contents, but for the reader who wishes to locate a specific item of information, an index would be a welcome addition. An extensive bibliography is appended. (Because this is a foreign language text, and somewhat difficult to obtain, the contents are reported in greater detail than is usual for a book review.)

Chapter I. Body measurements. These are divided arbitrarily into those of ''first order'': weight, height, thoracic circumference; bicrestal diameter and height of the pubis or iliac crest; and into those of second order: cranial and abdominal circumferences, bitrochanteric and biacromial diameters, circumferences of the arm and leg, upper and lower limb lengths, and thickness of the subcutaneous fat. Technics and errors are discussed for each type of measurement. Height is considered of greater value than weight as an index of growth because (1) there is less dependence on external circumstances for height; (2) height correlates closer than weight with chronologic age; (3) height is an expression of linear growth, a popular symbol of growth. The author's system of graphic representation, which will be commented on later, is based on this assumed accuracy of height as an index of growth. The wisdom of starting from this base may be questioned when one reviews the intercorrelation tables for anthropometric characteristics in Franzen's study (Franzen, R.; Physical Measures of Growth and Nutrition, American Child Health Association, New York 1929).

Chapter II. Analytical methods (with J. Teijeira). General and relative growth of the body and its parts is discussed in some detail. The authors derive their own equation of growth, corresponding to what is called a "fundamental curve of growth" which is formed by uniting points of change of slope in the standard bimodal growth curve.

Chapter III. Graphic methods of expression of growth (with J. Teijeira). Various methods are reviewed briefly and the authors' new method is described. The authors have constructed a grid with ordinates and abscissas of equal value. The former represents chronologic age, the latter, developmental age. The "normal" pathway would naturally follow an ascending bisector. Below the abscissa are additional scales, one below another, each scale having its own system of progression according to its correlation with age. Given one point on the grid, determined by the value of a measurement on one of the abscissa scales and the chronologic age on the ordinate, the developmental age is read from the primary grid scale. The appropriate values for the other measurements should be found in the vicinity of the perpendicular dropped from the original point where it intersects the different scales, parallel to the abscissa. Successive plotting of any measurement shows the direction and velocity of change of the measured characteristic, and relationships between several plotted characteristics are easily visualized. This method is actually comparable to others in use in which height-age, bone-age etc., are plotted against chronologic age. It has the advantage of depicting the numerical value of the standards for each characteristic and thereby eliminates the need for reference to tables. The standards used by the authors are those published by others for Spain, Italy and Argentina and may not be strictly applicable to children of different stock. The same graph is used for males and females up to three years; separate male and female graphs are available for the period from two years to 15 years.

Chapter IV. General methods of study of growth — Indices of Maturation. This chapter reviews methods which have little application to the daily problems of growth and development. Four subheadings are included: (1) medical — biographical, including photography; (2) experimental — under this heading are discussed tissue culture, the index of cicatrization of Leconte Du Nouy, and animal experimentation; (3) biochemical methods; and (4) biological methods.

Chapter V. Bone growth (with J. Pena and S. Sanx). The authors clarify historical sequences in the development of radiographic technic for evaluation of skeletal maturation, adding the name of Federico Oloriz y Ortega to the list of pioneers in the field. Examples of assessments made with the Greulich and Pyle atlas are illustrated together with other biologic data for each individual. Several plates suffer from errors by printing radiographs of knees upside down. In plate V, the ''ringed'' epiphyses in the upside down knee are so different from epiphyses in other regions illustrated, as to suggest an even more serious error.

A separate section is devoted to the correlation of alkaline phosphatase levels in the blood and age. The authors find alkaline phosphatase in both males and females highest under one year of age. There is then a gradual decrease, comparable in both sexes, but a prepubertal increase is noted in females between 9–11 years and in males between 10–13 years. Both descend to adult levels after 14 years. The authors also compare levels of alkaline phosphatase in normal children with the most advanced and most retarded bone age and demonstrate high levels in acceleration and low levels in retardation. They feel that the level of alkaline phosphatase is a better index of the prepubertal growth spurt than are either increments of height or bone age, and thus that chemical determination is the most sensitive indicator of the process of bone growth.

Chapter VI. Muscular development (with J. Pena). Muscular area of the calf in antero-posterior projection is measured with a planimeter on the x-ray film using points related to tibial length for limits of the area measured. Correlations with creatinine excretion are presented, as are those with height, weight and age. The area of the calf muscle is shown to correlate closely with creatinine excretion and total weight. This observation reflects similarity of interest in lean body mass as an index of biologic activity as shown by current studies at various centers in this country.

Chapter VII. Radiographic method of measurement of the panniculus adiposa of the anterior abdominal wall. The clinician is accustomed to palpate the thickness of the subcutaneous fat of the anterior abdominal wall on a child as an indication of nutritional status; the fullness of the buttocks is also observed. The authors have applied roentgen technics to the measurement of the former, believing the abdominal subcutaneous fat to be the first to respond to metabolic exigencies in malnutrition. Soft tissue films are obtained in direct lateral projections, during sleep, under physical factors described in the text, and the thickness of the fat is measured. The author does not state at what level in relation to the umbilicus the measurement is made. This procedure seems an unwieldy and rather empirical one; in keeping with the statistical practice of attributing greater accuracy to a large number of observations, the technic used by Garn

(Human Biology, *26:* 59–69, February 1954) would appear to offer better information.

Chapter VIII. Sexual maturation. The morphologic and physiologic changes in males and females are reviewed and related to hormone production during adolescence. The usual skeleton indices, epiphyseal closure, and the appearance of certain secondary ossification centers are described.

In general, this volume is a directory for sources of basic data with respect to growth, with brief but succinct commentaries on many phases of the subject. No great innovations are introduced, but sound support is provided for many of the current activities in the field. The volume is a worth while addition to any library, providing a broad perspective not generally found in so relatively few pages.

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THE ANCIENT INHABITANTS OF JEBEL MOYA (SUDAN). By Ramkrishna Mukherjee, C. Radhakrishna Rao and J. C. Trevor, pp.xi + 123. $7.50. With appendices by Frank Addison and the authors. Cambridge University Press. 1955.

This book is number III of the *Occasional Publications of the Cambridge University Museum of Archaeology and Ethnology.* It is a report on the skeletal material, dating from the first millennium B.C., excavated between 1911 and 1914 at Jebel Moya in the Southern Sudan by expeditions supported by Sir Henry S. Wellcome. Although 2903 individuals were recovered, the remains now consist of only 98 crania, 139 mandibles, some long bones (of which the most numerous are 70 right femora), 9 fragmentary pelves, and a few other skeletal parts. Before it was made the subject of laboratory study, a major portion of the material disintegrated beyond recovery while in storage in a succession of warehouses in or near London between 1914 and 1946. The loss was not total because records of field measurements on some 1461 individuals are available. These measurements were made by D. E. Derry (2nd season), M. B. Ray and L. H. Dudley Buxton (3rd season), and R. S. Oldham, W. D. Hambley and L. Hussey (4th season).

The major portion of the text is devoted to a discussion of 4 problems: (1) The reliability of the sex identifications of the skeletons in the field. (2) The comparability of the field measurements and observations with regard to differences between the observers and teams of observers and with regard to the standards now widely used in Britian. (3) The anthropometric evidence relevant to the suggestion from archeological evidence that a small number of possibly non-Negroid, mostly male immigrants settled at Jebel Moya about 1000 B.C. (4) The biological affinities between the ancient inhabitants of Jebel Moya and 20 other skeletal populations from Egypt, East and West Africa.

The field determinations of sex are shown to be unreliable. The techniques of measurement and observation used in the 3rd and 4th seasons are found to be not strictly comparable either with those of the second season or those employed by the modern British Biometric School. It was necessary, thus, to restrict the statistical analysis of the anthropometric characters to the surviving specimens and the cranial and femoral records available for the missing specimens from the second season's excavations.

The Jebel Moya series is regarded as homogeneous in regard to its internal anthropometric consistency. The skeletal material does not support (nor can it fully deny) the hypothesis that a small number of male non-Negroid immigrants joined the population in the first millennium B.C.

D^2 was used to measure the biological distance between the Jebel Moya and 20 other skeletal series. The comparisons are based on 7 cranial and 10 mandibular characters. The results of the analysis are such that the authors leave open the question of the precise biological affinity of the people of Jebel Moya. They suggest, however, that they are allied to the present-day Negroids of the Sudan.

The appendices attached to the text are as follows: I, The Stratigraphy of Site 100 (by Addison); II, The Mathematical Sexing of the Jebel Moya Series (by Rao, based on a discriminant function using two sets of measurements — 6 on the mandible, and length of femor, tibia, humerus, radius and clavical); III, A Quantitative Analysis of some Cultural Traits of the Jebel Moyans (by Mukherjee); IV, The Concept of "Distance" between Two Groups (by Rao); V, Mean Measurements of the Jebel Moya Series according to Stratum (by Mukherjee); and VI, Final Comments on Problems and Methods (by Trevor).

The authors have accomplished the best possible job of analysis of extremely unsatisfactory material. The available data are not able to provide firm knowledge with regard either to the detailed characteristics of the population during the periods represented by the 4 strata at Jebel Moya, nor with regard to the details of their biological relationships with other populations.

The book is noteworthy as the first large attempt to apply modern methods of multi-variate analysis to problems of the classification of human populations using skeletal material. In this sense it is a permanent landmark in the development of anthropological methodology. This judgement is not lessened by the fact that, because of limitations of the available data, certain makeshifts used in the statistical analysis are not fully justified. These were necessary if the analysis was to go forward; the authors have used care to label them as makeshift.

The known defects of the Coefficient of Racial Likeness have led some American anthropologists to be suspicious of all statistical approaches to the problem of classification. D^2 is a statistic which overcomes these defects. It is not a probability statement. Rather it is a measure of the amount of divergence between two groups. And it is a measure which corrects for the correlation between anthropometric characters by transforming the observed raw differences in such a way that one character will, in a defined sense, be equivalent in classificatory weight to each of a set of other characters.

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BOOK NOTES

THE VERTEBRATE BODY. By A. S. Romer, 2nd Ed., pp. viii + 644. W. B. Saunders Company, Philadelphia. 1955.

While the general pattern of this very successful text on vertebrate biology has been retained, minor revisions in organization, the addition of recent data and corrections to the first volume improve this latest edition. As when it was first published, this treatment of the comparative anatomy of vertebrates is not only outstanding in its quality of coverage and breadth but remains unique in the amount of attention given to the form-function relationship.

F.P.T.

A SOURCE BOOK IN ANIMAL BIOLOGY. By Thomas S. Hall, pp. xv + 716. McGraw-Hill Book Company, Inc. 1951.

Over 100 classical contributions to animal biology from the 15th to 20th centuries are given in the original — or translated into English — and organized so that the student can get some idea of the development of thought in this field and in the words of those who produced it.

THE EVOLUTION OF THE VERTEBRATES. By E. H. Colbert, vii + 479. John Wiley & Sons, Inc., New York and Chapman & Hall, Ltd., London. 1955.

This is a general introductory textbook on vertebrate paleontology. Extensively illustrated and quite complete in its coverage, it includes as one of 30 chapters a 20 page discussion on the evolution of the primates.

F.P.T.

THE NON-HUMAN PRIMATES AND HUMAN EVOLUTION. Arranged by James A. Gavan, pp. 134. $3.75. Wayne University Press. 1955.

This volume, in memory of Professor Hooton, presents in book form the articles first delivered at an A.A.A.S. symposium on December

27, 1953 and which were published in the September 1954 issue of HUMAN BIOLOGY. It is an important contribution to primatology by a group of outstanding authorities.

F.P.T.

DIE GLOCKENBECHERLEUTE IN MITTEL- UND WESTDEUTSCHLAND. EIN BEITRAG ZUR PALÄANTHROPOLOGIE EURAFRIKAS. By Kurt Gerhardt, pp. x + 212, 13 Tafel. E. Schweizerbart'sche Verlagsbuchhandlung, (Erwin Nägele), Stuttgart. 1953.

This is an account of the skeletal remains of ''bell beaker'' people from 130 sites in Middle and West Germany. Skull measurements by individual and site and by type groups are analyzed. A summary discussion of the whole population and its archeological status is given in this careful and detailed report.

F.P.T.

APES, ANGEL, AND VICTORIANS. THE STORY OF DARWIN, HUXLEY, AND EVOLUTION. By William Irvine, pp. 399. McGraw-Hill Book Company, Inc., New York. 1955.

This is the most thorough of the recent books which have come out on the life and times of the evolutionary idea and its originators and advocates. It is a scholarly book which should enjoy considerable popularity because of its lively account of interesting lives and an important intellectual revolution. It is not a very good account of the evolutionary idea or of the social mileau which influenced its beginnings, nor is any good conception of the present status of modern evolutionary theory used to tie Darwin's contribution to the present. It is a fine account of the intellectual lives of Darwin and Huxley.

F.P.T.

POMP AND PESTILENCE. INFECTIOUS DISEASE, ITS ORIGIN AND CONQUEST. By Ronald Hare, pp. 224. The Philosophical Library Inc., New York. 1955.

This book gives a most interesting discussion of the ways in which man and his changing numbers and social organization have affected his parasites, and conversely how parasites have affected human history. The author, a bacteriologist, sees the evolution of man and his society intimately tied up with the parasites which have come to favor him as their host and how these organisms have adapted to each other. Numerous references and extensive documentation make this a book of considerable value.

F.P.T.

ENSAYO SOBRE GEOMETRÍA CRANEANA. By Javier Romero, pp. 43. Instituto Nacional de Anthropologia e Historia, Mexico. 1955.

Romero and 4 collaborators have prepared this short discussion of the methods used in cranio-geometry and the comparisons of findings on a series of 100 Mexican prisoners with some other series. It is primarily an instructional paper which reports ranges and means for the various angles, lengths and indices mentioned.

F.P.T.

THE HIP JOINT IN LAPPS, AND ITS BEARING ON THE PROBLEM OF CONGENITAL DISLOCATION. By Bernhard Getz, pp. 81. Acta Orthopaedica Scandinavica. Supplementum No. 18. Munksgaard, Copenhagen. 1955.

The unusally high frequency of congenital hip dislocation in Lapps (4.2% of the total skeletal material reported here and 6.8% for females) is explained as a consequence of the shallow acetabulum and the frequencies of extreme antetorsion found among these people. Clear indications of a heritable factor predisposing to these hip characteristics was found. Yet the authors finds no single explanation efficient in accounting for the underlying cases of the unusual dislocation frequencies as both genetic and functional factors seem at work in shaping the unusual hip morphology of these people.

F.P.T.

ZWILLINGSANATOMIE. DIE ANATOMISCHE UNTERSUCHUNG BEI DEN ZWILLINGSFETEN, MIT BESONDERER BERÜCKSICHTIGUNG DER MENSCHLICHEN ERBFRAGEN DER SOG. NORMALEN UND ABNORMALEN MERKMALE. By Toratoshi Taniguchi, 57 pp. Kyorin-Syoin, Tokyo. 1955.

This booklet is a most welcome guide to the anatomical investigations carried out during the last 20 years on Japanese twin fetuses at the Anatomical Institute of Keio University in Tokyo under the direction of Professor Taniguchi. Dissections of about 100 pairs of twins (of which about 6/10 are monozygous, 3/10 dizygous, and 1/10 are of uncertain zygosity) have been reported in some 150 publications. Western workers are familiar with numerous papers which appeared in Okajima's *Folia Japonica Anatomica* but the large volume of material which has appeared in Japanese in Taniguchi's publication (Sōtaiji no kaibōgakutcki kenkyū (Research on the dissection of twin fetuses), Tokyo, 1937, 23 parts, each with 4–12 papers) is not well known in the West.

The present booklet gives an overview of the work in 12 sections: Causes and mechanisms of twinning, Comparisons of twins and singletons, Comparisons of MZ and DZ twins, Genetics and the expression of variations, Penetrance of variations and relationships to laterality. The similarity of various measured and enumerated traits, Sex differences, Inheritance of normal and abnormal characters. The ascending and descending tendencies of the origins of nerves and muscles, So-called normal and abnormal man, Mirror imaging, Symmetry and asymmetry.

The terminal list of literature (14 pp.) is a handy guide to the publications of Taniguchi's Institute and to other selected publications on twin anatomy. Titles of works published in Japanese are given in German.

J. N. SPUHLER

PROCEEDINGS
OF THE TWENTY-FOURTH ANNUAL MEETING
OF
THE AMERICAN ASSOCIATION OF PHYSICAL ANTHROPOLOGISTS

The twenty-fourth annual meeting of the Association, held in Philadelphia on Monday, Tuesday, and Wednesday, April 4, 5, and 6 at the invitation of the Jefferson Medical College, The Wistar Institute, and the University Museum and in conjunction with The American Association of Anatomists, included sessions at each of these institutions and a visit to the Philadelphia Center for Research in Child Growth. This provided a varied coverage of research centers in Central and West Philadelphia based on the Bellevue-Stratford Hotel.

Monday's general sessions were held at the Daniel Baugh Institute of Anatomy of the Jefferson Medical College, 307 South 11th Street, following a welcome by Professor N. A. Michels representing the department of antomy. At 4: P.M. the center of gravity shifted to a tour and cocktail party given by Dr. W. M. Krogman at his Growth Center, an affiliate of Children's Hospital and of the University of Pennsylvania's Graduate School of Medicine. The annual business meeting and smoker were held in the Burgundy Room of the Hotel Bellevue-Stratford on Monday evening.

On Tuesday morning a symposium on population genetics and the races of man, organized by Dr. James N. Spuhler, was held at The Wistar Institute of Anatomy and Biology, 36th Street and Woodland Avenue. This was followed in the afternoon by a symposium and discussion arranged by Dr. Gabriel W. Lasker on anthropology and medical education. Held in the main auditorium of the University Museum, this was organized as a guide toward discussion of this subject at the 1955 Teaching Institute of the Association of American Medical Colleges, and was followed by a demonstration of the cast collection and distributing facilities of the American Institute of Human Palaeontology under guidance of Dr. Loren Eiseley, head of the department of anthropology of the University of Pennsylvania. The annual dinner, attended by 82 people, was held in Kugler's Restaurant, and was the occasion for an address by retiring president William L. Straus, Jr. on the training of the physical anthropologist. He briefly traced the circuitous course of development of physical anthropology from the Darwinian 1850s onward, seeing it at that time in the hands of such anatomists and medical men as Cunningham, Turner, Beddoe, and more recently Keith in England, Broca, Topinard, and Manouvrier in France, Virchow and Welcker in Germany, Retzius in Sweden, Meeks and then Hrdlička, Todd, and Terry in the U.S.A.; with such biologists as Flower, Huxley, Owen, Galton, Vogt, and de Quatrefages less influential. After 1900, partly through the efforts of Franz Boas, there arose the idea of the ''compleat anthropologist'' trained (at least with a smattering) in all branches of cultural, archaeological, and physical anthropology. This synthesis was born of the facts that physical anthropology posts were few and that anthropology was establishing itself as a separate science. But now the problems which face physical anthropologists in their special field demand a reorientation in training. It is time to train a group of people broadly and deeply in biology, including also genetics, biostatistics, comparative anatomy, embryology, all three branches of anatomy, pathology, mammalian physiology, and at least elementary biochemistry. This is not a plea for uniformity. Physical anthropology has been morphological so that we have discussed the physiology of racial characters, for example, without having the basic measurable physiologic data. This area is being developed by those working in blood-groups, in growth, in experiments with the non-human primates, and to some extent, in the fields of posture, locomotion, and bone-stress-resistance. But there is scarcely a recognition yet of the need for more physiologically-oriented training for physical anthropologists in general.

The Wednesday morning session, held in the Clinical Amphitheater of the Jefferson Medical College, comprised the first six papers on the program of the American Association of Anatomists given by people who were members of both associations, and the afternoon session stressed functional anatomy and evolution.

BUSINESS MEETING, APRIL 4, 1955

President William L. Straus, Jr. opened the meeting with the call for brief obituaries of the three members lost from the Association by death during the past year: Professor Earnest A. Hooton, Father Cornelius J. Connolly, and Professor James H. McGregor. Dr. W. W. Howells, calling attention to the memorium for Dr. Hooton published in the Journal (AJPA, n.s. *12:* 445–453, 1954), noted simply that Dr. Hooton died unexpectedly at his home in Cambridge on May 3, 1954, having made great and unforgettable contributions to physical anthropology in U. S. A. and in the world as a whole. Dr. T. D. Stewart noted that after birth in Nova Scotia in 1883 and college and theological studies at the Grand Seminary in Montreal Father Connolly was sent by his bishop to Munich where he received the Ph.D. degree in biology in 1911. He taught at St. Francis Xavier University in Nova Scotia until 1923, and after a sabbatical year at Harvard taught in comparative psychology and then in physical anthropology at Catholic University of America where he became head of the department of anthropology and did long research on brain morphology. Born in Ohio in 1872 and first educated at Ohio State University, Dr. James H. McGregor received his Ph.D. from Columbia University in 1899, where he taught until retirement in 1942, serving as professor of Zoölogy after 1924. From 1916 onward he was a research associate at the American Museum of Natural History, in connection with his work in reconstructing facial features of early human types, and he was joint leader of the Museum's and Columbia University's joint African expedition in 1929–30. He was known for his many kindnesses to students as well as his interest in Primates. All three of these men were members of the American Association of Physical Anthropologists from its founding onward.

President Straus named the members of the following committees: Nominating Committee, including Dr. T. Dale Stewart (chairman), Dr. W. W. Howells, and Dr. Gabriel W. Lasker; Viking Fund Award Committee, Dr. W. W. Howells (chairman), Dr. T. Dale Stewart, and Dr. W. L. Straus, Jr. (Dr. Mildred Trotter, succeeding Dr. Straus as president, has since enlarged the Viking Fund Award Committee by the addition of Dr. C. W. Dupertuis, Dr. Loren C. Eiseley, Dr. C. W. Goff, and Dr. W. S. Laughlin.)

After approval of the minutes of the 23rd annual meeting (Proceedings in A.J.P.A., n.s. *12:* 273–282, 1954), the Secretary pointed out that the membership increase was tending to reach a plateau (1930, 109; 1942, 153; 1952, 300; 1954, 345) with a 1955 addition of 19 new members. Approved earlier by the Executive Committee and now submitted for ratification:

Ananthanarayana Ayer
Edward Bruner
Donald C. A. Butts
Bruce Chown
Thomas K. Cureton
Robert H. Dyson
Edward I. Fry
William Godfrey
Bertram L. Hanna
Marion Lewis
Richard Rosenfield
S. Sangviechien
G. W. H. Schepers
Richard Stucklen
Paul Swenson

Newly approved by the Executive Committee:

Harry W. Basehart
Emil Breitinger
S. R. K. Chopra
Joan Finkle DePena
Margery P. Gray
Bonnie M. Jones
Alec John Kelso
Ellis R. Kerley
Frank B. Livingstone
Roy Paul Mackal
John C. McGregor
Matthew Mitchell
Louana Pettay
Benjamin D. Paul
Alice Bro Racher
Karl V. Sarnas
William J. Schull
Fred Wendorf

All these candidates were moved accepted by Dr. C. E. Snow and elected unanimously.

Reporting on the relations of the Association with the American Association for the Advancement of Science, Dr.

W. Montague Cobb noted that in June 1953 he had learned from Dr. Gabriel Lasker, Secretary of Section H, of the proposed change of meeting site of the AAAS from Chicago to Atlanta for the 1955 meetings, had been informed that the ''Jim Crow'' segregative practices of the State of Georgia could not be revoked except on the campuses of Georgia Tech and Atlanta University, and had stated to Dr. Raymond Taylor the reasons why such arrangements were not fitting for a scientific meeting. After the Association had become an affiliate of the AAAS with Dr. Cobb as one of its representatives he had inquired at its 1953 Boston meeting of its Board of Directors if the AAAS had not previously passed a ruling to meet only in places where all its members would be treated equally; Dr. Meyerhoff, then AAAS Secretary, agreed this was likely but then could find no record of such an action in the Council minutes back to 1935. In December, 1954, when Dr. Cobb was elected chairman of Section H and a Vice-President of the AAAS he noted that he personally decided not to go to the Atlanta meetings, even writing to the President of the United States about this and other matters of segregation. Dr. W. W. Howells, the other representative of the Association to the AAAS, added that it was his understanding that Section H would not participate in the Atlanta meetings of the AAAS since such action would be condoning segregation, and Dr. Lasker agreed that the majority of the members of Section H had so decided.

After considerable commending discussion of these actions and data by the membership, Dr. Howells proposed a resolution, seconded by Dr. J. N. Spuhler, as follows:

> "Whereas the American Association of Physical Anthropologists cannot by principle hold meetings or participate in meetings in places where racial segregation is practiced, be it resolved that the Association hereby associate itself with the action of the committee members of Section H in declining to participate in the meetings of the AAAS in Atlanta in 1955."

After phrasing as above by Dr. Howells this resolution was unanimously adopted at the end of the business meeting.

President Straus appointed the Secretary, Dr. J. L. Angel, to replace Dr. Cobb as representative of the Association to the AAAS.

The reports of the Treasurer and of the Auditing Committee were read; Dr. C. E. Snow moved they be accepted.

TREASURER'S REPORT

U. S. Savings Bonds (maturity value)			$2,500.00
Bank balances March 22, 1954, in Fidelity-Philadelphia Trust Co.:			
Savings account			$2,018.84
Checking account			1,175.61
Receipts:			
Annual dues	$2,216.00		
Postage from foreign members	25.15		
Sale of STUDIES	6.00		
U.S. Savings Bond due (no. D 89594F)	500.00		
Sale of Prudence Bond, principal	75.00		
Prudence Bond, back interest	172.35		
Bank, exchange credit	.08		
Interest on Savings account	18.98		
		$3,013.56	
			$6,208.01
Expenditures:			
To Wistar Institute (subscriptions)	$1,543.00		
To Wistar Institute (Proceedings)	90.90		
To Wistar Institute (program)	76.08		
To Bertram Kraus (Newsletter)	140.00		
Secretarial expenses	191.62		
Foreign members mailing	22.50		
Bank, exchange charges	1.00		
		$2,065.10	
Bank balances April 1, 1955:			
Savings account (including $1,400 deposit)		$3,437.82	
Checking account		705.09	
			$6,208.01

Respectfully submitted
J. LAWRENCE ANGEL, *Treasurer*
April 1, 1955

Certified to be as stated above.
April 4, 1955
BERTRAM KRAUS
J. N. SPUHLER
Auditing Committee

Dr. W. W. Howells, the retiring Editor of the American Journal of Physical Anthropology, reported on Volume 12, new series. He pointed out that with 642 pages this was of considerably expanded size, and that Dr. Sherwood L. Washburn, the new Editor, had already enough good manuscripts to fill the first two numbers of Volume 13. Dr. Howells closed with heavy stress on the debt which the Association owes to The Wistar Institute for its steady and continued support of our Journal. Dr. J. L. Angel moved that the president write a letter of thanks offering to Dr. E. J. Farris, director of The Wistar Institute, the congratulations and support of the Association for his policy of maintaining long-continued publication of such scientific journals as the AJPA which although international in scope have relatively restricted circulation. Dr. Melvyn Baer moved that the Association express its appreciation of the high achievements of Dr. W. W. Howells' editorship of the AJPA over the past six years (applause).

President Straus speaking for the Executive Committee opened discussion of the Newsletter, criticising its personal report content as being much too uneven and suggesting that it contain news items, reports of jobs, lists of publications of members, and titles of dissertations. Dr. Hunt protested the loss of interest; Dr. Moss added the need for specialized bibliography; the editor, Dr. Kraus, mentioned the hesitation to edit personal news which some members want to have printed; and Dr. Krogman, stressing the need for this medium for exchange of information on work in progress suggested that a committee be appointed to act on the Newsletter. The president, Dr. Straus, thereupon appointed Drs. Krogman, Hunt, and Moss as members of this committee.

Dr. T. Dale Stewart announced that with support of a grant from the Wenner-Gren Foundation for Anthropological Research a Summer Seminar would be held this year in Washington, D. C. The subject of this seminar in physical anthropology, to be held from September 7 to 9, is "The role of physical anthropology in the field of human identification." There will be a series of five panel discussions in which government agencies such as the F.B.I. and Memorial Division will be interested. Dr. Mildred Trotter will assist in organizing the program, concerning which a fuller statement will appear in *Science*. All physical anthropologists are urged to attend and participants may test their identifying abilities on series of bone specimens of known race, sex, and age.

Dr. Wilton M. Krogman as chairman of the Nominating Committee (assisted by Dr. M. S. Goldstein and Dr. Fred Thieme) offered the following nominations: for president, Dr. Mildred Trotter; for executive committee member, Dr. W. W. Howells; and for associate editor of the Journal, Dr. Mildred Trotter. The nominees were elected unanimously.

The Resolutions Committee submitted the following report, which was moved accepted:

1. Be it resolved that the Association express its gratitude to the Daniel Baugh Institute of Anatomy of the Jefferson Medical College, to the University Museum of the University of Pennsylvania, and to The Wistar Institute of Anatomy and Biology for their parts in making facilities available to us.
2. Be it further resolved that the Association give grateful thanks to Dr. George A. Bennett, Dean of Jefferson Medical College and Director of the Daniel Baugh Institute of Anatomy, to Dr. Froelich Rainey, Director of the University Museum, and to Dr. Edmond J. Farris, Director of The Wistar Institute for their activities on our behalf.
3. Be it also resolved that the Association make known its appreciation to Dr. W. M. Krogman and to the staff of the Philadelphia Center for Research in Child Growth for their courteous and gracious hospitality.
4. Be it further resolved that the Association's gratitude be expressed to our Secretary-Treasurer, Dr. J. Lawrence Angel, for his continuing activities in our behalf and for his success as chairman of the local committee.
5. Be it further resolved that the Association thank Dr. Paul Fejos and the Wenner-Gren Foundation for their continued support of physical anthropology both here and abroad, and to Dr. E. J. Farris and The Wistar Institute for their friendly assistance to our Journal and Association.
6. And, whereas Dr. W. W. Howells has served as Editor of the American Journal of Physical Anthropology, bringing to it his great

literary skill and broad interest in physical anthropology while fruitfully collaborating with allied journals, let us therefore formally record our appreciation.

7. And, whereas the Association has lost three of its valued members and founders, C. J. Connolly, E. A. Hooton, and J. H. McGregor, be it resolved that the Association extend its most sincere sympathies to the bereaved families.

Respectfully submitted,
MILDRED TROTTER
STANLEY M. GARN

The Secretary announced the probability that the 25th annual meeting of the Association would be held in Chicago at the beginning of April, 1956, since Dr. S. L. Washburn had extended an invitation to meet at the University of Chicago, with the further possibility of meeting jointly with the American Society of Human Genetics.

Under New Business the executive committee suggested that expansion of the Association's membership would be facilitated by establishing two classes of membership. After adequate discussion, almost all of it critical of the proposal, a sentiment vote called for by Dr. R. W. Newman showed the majority in favor of retaining the present membership provisions, and the meeting was adjourned.

The scientific part of the program included the following papers:

1. *Are the Yupa-Indians genuine pygmies?* Martin Gusinde (Professor of Anthropology), Catholic University, Washington 17, D. C.

The first conquerors who began to open their way into the northern parts of Venezuela, about 1520, received rumors that some Indian groups there were characterized by a dwarfish bodily size. The following centuries have qualified these reports as wrong. Again during the last three decades occasional travelers have mentioned that the Indians on the Serranía de Valledupar, at the political border between Venezuela and Colombia, were real pygmies.

In modern Anthropology the term ''Pygmies'' does not indicate a special racial type. On the contrary, it serves exclusively as a term for classification, and designates a racial group whose men do not exceed 150 cm (= 59″) as mean size. To get sound evidence concerning this question, a methodical investigation of the Indians who live on the heights of the Sierra de Perijá, was carried out during June and July 1954, with the aid of grants from the Philosophical Society in Philadelphia, Pa. and the Catholic University in Washington, D. C.

The proper name of these natives is ''Yupa,'' and their whole population is divided into many ''rancherías.'' The number of the adults in such a ranchería varies from two to fifteen. So it happens that in some of these very small communities the average size of the male adults does not surpass the limit of 150 cm. Even if it would be proved that the total of the Yupa population are Pygmies, their small bodily size represents only a modification, as the result of miserable living conditions through generations. They are not racial Pygmies.

2. The Lange-U.S.A.F. contourometer, a new type of measuring instrument. H. T. E. Hertzberg and Frank P. Saul, Aero Medical Laboratory, U. S. Air Force.

This paper describes the Lange-U.S.A.F. contourometer, a new device which is capable of measuring the head and face in a more comprehensive manner than is possible with conventional instruments.

The contourometer is basically a camera with attached vertical stroboscopic light sources. The two sources, one on either side of the head, are shielded so that only a thin sheet of light is emitted. In operation, the sources are passed over the head and flashed at predetermined intervals. The resultant traces of the intersection of the light sheet with the surface of the skin, are recorded by the camera and provide the equivalent of a topographical map of the head. Coordinates for any point on the head may then be derived from this ''map.''

Possible adaptations of this tool to other portions of the anatomy are discussed, as are specific potential applications in anthropological, dental, and physiological research.

3. Cranial and facial growth in the Indian Knoll skeletons. Karl V. Sarnas, Eastman Dental Dispensary, Rochester, N. Y.

The present study was undertaken in collaboration with the Department of Anthropology, University of Kentucky, Lexington, Ky., and the objective is to determine the relative changes in cranial and facial skeletons during growth. A total number of 149 skulls were selected from the Indian Knoll collection as being in excellent or good condition, and separated into four age groups: (I) 3–9 yrs., (II) 10–19 yrs., (III) 20–29 yrs. (also separated by sex), (IV) 30–39 yrs.

Two groups of measurements were obtained from each skull: (A) Direct measurements of the cranial, facial and dental arch width inclusive its length. This group represents dimensions (n = 22) in the frontal plane and was recorded in 149 skulls. (B) Indirect measurements, by the use of cephalometric radiographs with regard to linear and angular dimensions (n = 32). This group represents dimensions in the median sagittal plane, and was recorded in 113 skulls.

Within each age group every dimension is correlated with the rest in turn, by means of the Pearson's product-moment method. A final analysis by following every coefficient of correlation through age group by age group are being made and the most important findings will be tabulated.

4. Roentgen cephalometric studies in normal and hypophysectomized rats. Henry R. Frank and C. Willet Asling, University of California School of Medicine, Berkeley and San Francisco.

A previous report (Am. J. Phys. Anthrop., n.s. *9:* 244, 1951) demonstrated a roentgen cephalometric technique applicable to serial studies in rats. The present report concerns 30 female rats on which repeated observations were made for 8 months, starting when 28 days old. Sixteen of the group were hypophysectomized on the initial day of the experiment.

Retardation of growth in skull length after hypophysectomy was proportional to retardation in body length (ultimately 16% short of normal). Cranial (i.e., neurocranial) length participated in this retardation. Cranial width, however, remained constant, having already achieved the adult definitive level at the outset. In consequence, the cranial width-length index which was 81 initially remained at this level throughout in hypophysectomized rats, but eventually dropped to below 70 in intact rats, reflecting their continued growth in cranial length. Cranial height responded like width; the height-length index (initially 50) was sustained in hypophysectomized rats, but dropped to 42 in intact rats.

Normally the facial component of the skull elongated faster than the cranial component; initially shorter, it showed equal length at 55 days of age, and thereafter exceeded cranial length. In hypophysectomized rats it remained shorter; the proportions eventually attained were those of 40–45 day old rats.

Some x-ray and histologic studies of the effects of this pituitary deficiency, and of hormonal replacement therapy, will be demonstrated.

5. *Inheritance of zygodactyly and ankylosis.* Joan Finkle dePeña, Department of Anthropology, Indiana University, Bloomington, Indiana.

Although there is some confusion in the literature, current views in human genetics define zygodactyly as webbing of the skin between two or more digits, syndactyly as partial or complete bony fusion between two or more digits, and ankylosis as fibrous or bony fusion of the interphalangeal joints. Varying modes of inheritance have been attributed to each of these traits. Zygodactyly has been reported as having holandric gene action, dominant autosomal gene action, and dominant sex-linked gene action. Syndactyly is believed to be an allele of zygodactyly and so inherited in the same manner. Ankylosis is described as generally inherited through dominant autosomal gene action. There is agreement only in that each of these phenotypic expressions shows considerable inter and intrafamilial variability of expressivity in degree, location, and mode of inheritance.

The current paper presented a four-generation pedigree in which the two characteristics of zygodactyly (webbing of the skin between second and third toes) and ankylosis (bony fusion of the right thenar metacarpal-phalangeal joint) are inherited as sex-linked dominants by the same individuals, with the exception of one female who does not exhibit any ankylosed joints. The location of the ankylosis present in the members of this pedigree is one not heretofore described, and its mode of inheritance is at variance with reported studies of this trait. The pedigree presented lends support to the belief that zygodactyly is inherited through dominant sex-linked gene action.

6. *Kinship and genetics.* Burt Aginsky, Department of Anthropology, City College, New York.

7. *The physical anthropology of the school-age children of Beth Mazmil.* Ailon Schulman, Hadassah Medical Organization, (Beth Mazmil), Jerusalem, Israel.

Beth Mazmil is a small residential village some eight kilometers southwest of Jerusalem. The Hadassah Medical Organization, which has a Family Health Center at this village, has been conducting a longitudinal Growth and Development project for the past two years. All school-age children are examined twice annually for medical measurements, nutritional assessments, and maturity grading.

The examinations of December 1954 were joint medical-anthropological. While the longitudinal study is to continue for some time, a cross-sectional analysis was conducted in order to evaluate methodology and results.

Some 550 children were examined. The two broad areas of origin were Europe and the Middle East. The study included both males and females. Age distribution ranged from 4 to 14. The physical anthropological examination was concerned with observations, measurements, and genetics (PTC, color blindness).

Certain of the data analyzed, and results of the evaluation of methodology, were felt to be the most significant aspects of the study.

DEMONSTRATIONS

A. *A model constructed to show typical ranges of limb-joint movement.*[1] Wilfrid T. Dempster, Department of Anatomy, University of Michigan, Ann Arbor.

The construction of test dummies with realistic joint movements requires a background of knowledge on link dimensions and the range and type of movement at each joint. The model to be demonstrated was fashioned so that specifications derived from a study of joint actions could be tested functionally in comparison with actual limb movements. Joints were constructed of universals, gimbals, hinges, or rod and sleeve units so that the correct degree of freedom at each joint was permitted; stops and templates were so placed relative to each joint that the range of joint motion was restricted to predetermined limits. Link dimensions in the several limb segments were scaled to correspond with those of an average male 69 inches tall and were based on the stature/bone length data of Trotter and Gleser. Globographic representations of the movements of cadaver joints and tabulations on joint range data from living subjects will be shown. In addition to data on dimensions, and the type and range of movement, assembly of the model required attention to the relative orientation of one joint to the next in sequence.

The paucity of background material on functional dimensions in the literature emphasizes a need for physical anthropologists to supplement the conventional anthropometry with meaningful data in this field. One important area relates to information on individual and cumulative joint ranges for selected populations and age and sex groups.

B. *Roentgenographic study of the vertebral column.* Meryl Miles and Walter R. Sullivan (Department of Anatomy, University of Wisconsin).

C. *Photographic study of bone pathology in Bronze Age Greece.* J. Lawrence Angel (The Daniel Baugh Institute of Anatomy of the Jefferson Medical College).

D. *Studies of the internal architecture of the femoral neck.* R. Cranford Hutchinson (The Daniel Baugh Institute of Anatomy of the Jefferson Medical College).

E. Constitutional variations in the hepatic blood supply. Nicholas A. Michels (The Daniel Baugh Institute of Anatomy of the Jefferson Medical College).

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[1] Supported by a contract with the anthropometric unit of the Wright Air Development Center, Wright-Patterson Air Force Base, Dayton, Ohio.

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8. An immunological test for syphilis in bone. Frederick P. Thieme, Department of Anthropology, University of Michigan.

Prepared extracts of known syphilitic and non-syphilitic bone which had been subjected to decay and limited ageing were examined with the Trepanoma pallidum Immobilization (TPI) test. In addition, known positive and negative human blood sera were treated by the same procedures involved in the preparation of the bone extracts for the TPI test. The positive sera and bone reacted positively and the known negatives negatively. It has been demonstrated that specific antibodies develop as a consequence of syphilitic infection and are present in life and that the TPI test is effective and specific in their detection. The results indicate that these antibodies can also be detected by this test after death. The duration of the antibodies post-mortem in detectable quantities is not known, however, concentrated extractions of bone or tissue may yield detectable quantities in ancient bone or tissue.

This test procedure is advantageous in the detection of syphilis in bone because it is a reaction directly and specifically related to the initial presence of *Trepanoma pallidum* and is not confused with other reactions as are most morphological indications of bone syphilis.

The research is continuing and involves the perfection of the extraction process and the extension of the test to older samples.

9. The significance of post-operative osteitis for the interpretation of pre-Columbian surgical procedures in Peru. T. D. Stewart, Division of Physical Anthropology, U.S. National Museum, Washington, D. C.

Little, if any, consideration has been given to the surgical handling of the soft parts (scalp) once forming part of the operative field in cases of pre-Columbian trephining recovered in Peru. Graña et al. ('54) speculate on this subject, suggesting that the Indian surgeons may have preferred curved incisions, but admitting that they could just as well have used straight incisions with short cuts at the extremities to produce rectangular flaps. Yet these authors produce no evidence. Quevedo ('44) sidesteps this problem, but on the other hand, reports evidence of surgical sutures in mummies and suggests that the scalp was replaced over the opening in the bone. Since soft parts are not preserved in most of the recovered specimens, is there any way of getting more information on this subject?

Several specimens in the U. S. National Museum (to be illustrated) show the outline of the scalp wound, owing to the development of postoperative osteitis during a short survival period. Apparently the infection spread only as far as the undisturbed periosteum. Other specimens (to be illustrated) show that even the healed osteitis still defines the limits of the original wound. In the past the osteitis has been misinterpreted as the reason for the surgery, rather than as the result; and the area of healed osteitis has been misinterpreted sometimes as the result of bone scraping.

Judging from this evidence and from certain mummies with trepanations preserved in Lima (to be illustrated), a large multiangular piece of scalp was often entirely removed prior to cutting the bone. Probably whatever tissue then regenerated over the bone ultimately fused with the cerebral membranes over the exposed brain, as Quevedo ('44) has demonstrated.

10. Additional data on Early Man in South America. Georg K. Neumann, Department of Anthropology, University of Indiana.

11. The racial relationships between Polynesians and American Indians. Marshall T. Newman, Division of Physical Anthropology, U. S. National Museum, Washington, D. C.

Revival of interest in trans-Pacific connections, particularly between Polynesia and the Americas, calls for a review of the physical evidences. Polynesians have more White traits than living Indonesians and American Indians and are larger than all but the tallest Indians. Metric data on skulls and living, give equivocal results and may be inapplicable to problems of racial affinities involving considerable time-space differences.

Blood groups seem more meaningful, but except for the ABO groups, Polynesia is represented by only a single Maori series. Polynesians are consistently higher in group A, except for a strip in northwestern North America. The marginal position of both peoples in the Pacific world is as good an explanation for this resemblance as trans-Pacific contact. In their moderate frequencies for M, the Maori stand closer to Indonesians than American Indians who are very high in M. The Maori are higher in ns and lower in mS than Indians, but have much less Sydney (S +) factor. Mostly the Maori are lower in Rh_1, higher in Rh_2 and may lack the rare Rh_z. Indians are probably wholly Secretor, contrasted with a 0.48 gene frequency for the Maori, who are conspicuously higher in P-antigen. If other Polynesians resemble the Maori, the marked serological differences between Polynesians and American Indians argue against direct racial connections. This does not deny the possibility of prehistoric trading connections, but only renders mass migrations between Polynesia and the Americas less likely.

12. Theory of the survival of the unfit. Marcus S. Goldstein, Public Health Service, Department of Health, Education, and Welfare, Washington.

A theory of the survival of the unfit (e.g., relating low infant mortality rates with genetic deterioration of the population), appearing in some recent anthropological and genetic sources, was critically discussed.

13. The relation of climate and body composition in young American males. Dr. Russell W. Newman, HQ Quartermaster Research and Development Command, Natick, Massachusetts.

The association of body size and shape with measures of the physical environment has been handicapped because the available measures of size and shape (total body weight and stature) are difficult to accept as indicators of functional homeothermic entities. The use of gross body weight as an indicator of the heat-producing mass of the body ignores the fact that at least two major bodily elements are subsumed by this value, the muscular tissue with accompanying fluids and the fat tissue. Data are presented which divide gross body weight on approximately 2,000 young American White males into two fractions which are more meaningful in this association. Fat free weight is equated with the heat producing mass of the body and body fat calculated from skinfolds is considered as a heat conserving layer surrounding the fat free mass.

Correlation coefficients, partial correlation coefficients, and multiple correlation coefficients between the biological measures (fat free weight and body fat) and climatic data (mean annual, mean January, and mean July temperatures) showed higher values than was found with a much larger series using only weight and stature. Although the interpretation of the statistical relationships between climate and these elements of body composition may be changed by subsequent and more extensive data, it appears that two climatic elements are involved in the problem, body fat being inversely proportional to summer heat and fat free weight inversely proportional to winter cold.

14. An experimental approach to the effect of climate on man. Paul T. Baker, HQ Quartermaster R and D Command, Natick, Massachusetts.

Anthropological thought concerning the effect of climate on evolution and race formation has gone through many fads. We still have very little fact. In such a situation, opinion rules supreme. By applying experimental procedures and utilizing physiological, psychological and anthropological techniques, we are now in a position to do definitive research. Past research done in the desert and in cold chambers indicated that the heat and cold resistance of individuals is closely related to their body composition and configuration. We may also test for racial differences in heat and cold resistance. A study was conducted at Fort Lee, Virginia to determine whether there is a difference between American Negro and White heat stress resistance. Forty-eight Whites and 48 Negroes were matched for body fat, fat free weight and stature. These men were exposed to equal heat stress by having them hold a walking pace of 3½ miles per hour for one hour. Sweat loss, rectal temperature, and pulse rate were recorded. During the experimental period weather conditions were cooler than normal for Virginia in August. Rectal temperature was significantly lower for Negroes than Whites. Sweat loss, and pulse rate differences were not statistically significant.

The results of this study can be considered as only indicative in that the heat stress was low. Even so, it exemplifies the potential of the approach. The instrumentation and technique is simple enough to apply in the field on native populations. If we had data on the heat and cold resistance of even a few world populations we would have a solid basis on which to speculate about man's relationship to his climatological environment.

15. Some statistical properties of body size data. I. Edmund Churchill, U.S.A.F. Anthropometric Project.

Two aspects of the statistical nature of body size data have been investigated using data on 132 dimensions from a series of 4,000 USAF me and on 63 dimensions from a series of 850 USAF women. The first aspect is the degree of departure of the data from symmetry; the second is the accuracy with which certain percentiles can be estimated from the means and standard deviations. The results are summarized by body segments and by type of dimension (long bone lengths, fleshy circumferences, etc.).

SYMPOSIUM: POPULATION GENETICS AND THE RACES OF MAN AT THE WISTAR INSTITUTE OF ANATOMY AND BIOLOGY

Chairman: J. N. Spuhler

16. Human genetics, morphological types, and racial history. Edward E. Hunt, Jr., Forsyth Dental Infirmary.

Despite the brilliant ascendancy of serology in recent studies of racial history, anthropometry is still a useful technique in this field. One of the more controversial anthropometric methods, however, is the subdivision of metrical series into morphological types. This historical approach is especially evident in the major works of Hooton and his students on racial history.

Each type is a partial sector of the total variability of the sample, and is defined on the basis of a small number of convenient metrical and morphological ''sorting criteria.'' The investigator usually regards some of these types as approximations of ancestral strains which have mixed to produce the population which he has measured.

According to this reasoning, each ancestral stock should have been less variable than the later anthropometric series. Yet modern studies of race mixture indicate no increased variability in hybrid groups. Some quite variable samples of fossil man are also known — to say nothing of living isolates of lower primates.

The survival of relatively numerous, putatively ''ancestral'' morphological types in a human population should not be expected on the basis of hybridization followed by prolonged panmixia. Furthermore, ancestral chromosomal entities should eventually disappear through crossingover, so that linkage cannot explain the long persistence of these types either.

If certain types are strikingly prevalent in a population, data should be obtained in the field on whether they tend to be the progeny of homogamous matings. Williams ('31) found that homogamy occurred in near-Indians in Yucatan, as well as in near-Whites. Selection and differential fertility should also be considered, such as the possible rapid evolution of alien groups toward local metrical and morphological averages in the absence of exogamy. Such may be the case among the descendants of Albanians and Northern Italians in Southern Italy, according to Gini ('54).

The occurrence of linkage in recently hybridized groups is another profitable field where constellations of morphological features may be employed. Rife ('54) has pioneered in this field in his studies of Sudanese and Americans of mixed Negroid and White ancestry.

The foregoing limited uses of statistically associated physical traits can be justified on genetic grounds. But in the absence of adequate knowledge of the ancestral strains which have blended in a living population, the reconstruction of what Radcliffe Brown calls the "conjectural history" of human groups from morphological types alone has no secure genetic basis.

17. *A genetical study of the nuclear (ghetto) Jewish community of Rome.* L. C. Dunn, Columbia University Institute for the Study of Human Variation.

Of the 12,000 inscribed members of the Jewish Community of Rome, about 4,000 constitute an endogamous social group recognizable by family names, residence, occupation and common use of social services and institutions. These are descendants of families enclosed in the Roman Ghetto 1554–1870. Historical continuity since 70 A.D. is indicated. A gene frequency study (8 blood-group systems, thalassemia, sickling) of some 650 members, including 60 complete families, of this nuclear community is reported. Some differences in gene frequencies between this and other Italian communities (e.g. higher B, r′, etc.) indicate partial reproductive isolation from neighboring populations. Comparisons are made of gene frequencies in this and other Jewish communities.

18. *The usefulness of blood factors in racial anthropology.* R. Ceppellini, Università di Milano and Columbia University Institute for the Study of Human Variation.

With the aim of studying the possible effect of malaria as a selective agent upon genetically controlled blood anomalies, red cell osmotic fragility test, hemoglobin electrophoretic analysis and blood typing were done on 1000 individuals belonging to four Sardinian villages. In the two villages located in a low valley where malaria has been endemic until recently, 19% and 24% of the inhabitants showed a markedly decreased osmotic fragility, which suggests a corresponding high frequency of the thalassemic trait, whereas in the two other villages up in the hills and thus malaria-free, only in 4% and 5% of the subjects was this hematological anomaly detected.

The Rh and MN frequencies were not significantly different in the 4 villages and well within the typical values known for Sardinia, but the ABO frequencies showed statistically significant differences for each village.

The genetical mechanisms which can give rise to such a situation are discussed and the value of ABO blood groups in ethnological work is called into question; this leads to doubts about the usefulness of certain blood group systems in anthropology.

19. *Applications of biochemistry to the study of population differences.* H. Eldon Sutton, Institute of Human Biology, University of Michigan.

Biochemically man is an array of enzymes, each controlled by the genetic constitution of the organism and each capable of carrying out one or more specific chemical reactions. These enzymes react with the chemical environment forming products whose levels in the body are controlled by the quantity of enzyme, the amount of substrate in the environment, other metabolic products, or combinations of these. All aspects of the individual including the anthropometric actually reflect his biochemical nature, but it is convenient to consider together those measures based on similar methods of analysis.

As yet there are no methods for measuring genes directly. The enzymes probably reflect genetic differences very strongly, but these have not been studied extensively from the genetic and population aspects. Some genetic studies have been carried out on the chemical products of enzyme activity, in particular, the amino acids of the urine. There is ample evidence that the amino acids are excreted at levels characteristic of the individual. There is also evidence for some of the amino acids that the differences between individuals observed are genetic in origin, presumably reflecting differences in the activity of certain enzymes. That they can also be altered by the diet and certain other environmental factors such as stress can also be shown.

In attempting to detect racial differences in biochemical traits, it is therefore necessary to work with the different racial groups in similar environments. Such a study has been carried out comparing the amino acid excretion of Chinese with Caucasoids. Urine samples were collected from 18 Chinese and 33 individuals of Western extraction, all living in Ann Arbor. Quantitative paper chromatographic analyses of amino acids showed that the Chinese excreted more β-aminoisobutyric acid, lysine, leucine, histidine, and tyrosine. These differences are believed to be largely genetic since in some instances a husband or wife might consistently excrete markedly different amounts from the spouse. In the case of the β-aminoisobutyric acid, the difference results from the existence of more ''excretors'' in the Chinese population. In Western populations, less than 10% of the population fall into the high excretor group, while in this sample of Chinese, 50% of the subjects were high excretors.

If the conditions can be worked out for recognizing the presence of specific genes through their biochemical effects, such biochemical traits may someday be used to compare populations just as are the blood groups today.

20. The distribution of blood-types among Indians of Washington and British Columbia. Frederick S. Hulse, Department of Anthropology, University of Washington.

During the last few years much data have been collected on the blood types of Indians in Washington and British Columbia. Since this area is near that occupied by the Blackfoot, among whom blood-group frequencies are quite distinctive, the results should tell as much of prehistoric relationships.

Methods of collecting and of testing blood are described. Field problems and the lessons learned from them are recounted. Types of sera and equipment suitable for use under differing circumstances are listed. A summary of results, by tribal groups, is presented. It is clear that considerable variation, in the incidence of some genes, exists between different populations.

The data collected, and the gene frequencies calculated therefrom, are discussed in the light of known and inferred past contacts and tribal movements, and of present geographical locations. Various clines are shown to exist. Problems arising from the small size of typical populations, and from known contact with Caucasians, are dealt with.

Many more populations will need to be examined in order to provide a complete picture of genetic relationships throughout the Northwest, but the data on hand confirm the hypothesis of population drift towards the coast.

21. Coefficient of between-population relationship for gene-frequency data. J. N. Spuhler, Institute of Human Biology, University of Michigan.

The volume of gene-frequency data on the known, simply inherited serological characters in man has reached a magnitude which precludes easy appraisal of between-population relationships by inspectional techniques. An easily calculated coefficient of relationship is proposed for measuring the biological distance between any number of populations taken 2 at a time for any number of gene frequencies.

Since all of the serological characters commonly used in anthropology are genetically and statistically independent, a quadratic expression may be used to measure the distance between any pair of k-fold points in k-dimensional space, where k is the number of independent genes known in common for the populations.

Let i_1 be the i-th gene frequency in the 1st population, and i_2 be that in the 2nd population, and define $d = i_1 - i_2$. The coefficient of relationships, R, may be bounded such that $0 \leq R \leq 1$ by dividing the square root of the sum of d^2 by $\sqrt{k}$ where k is the number of gene frequencies which enter the summation:

$$R = \sqrt{(\Sigma d^2/k)}.$$

As usually estimated only n — 1 of n allelic frequencies are independent and only n — 1 should be used in the coefficient.

If none of the genes whose frequencies are used in the coefficient are linked, the standard deviation of R is given by

$$\sigma_R = \sqrt{[\Sigma(\sigma i_1{}^2 + \sigma i_2{}^2)/k]}$$

where $\sigma i_1{}^2$ is the variance of the i-th gene frequency in the 1st population and $\sigma i_2{}^2$ that in the 2nd population.

Use of R in classification is illustrated by considering all possible classifications of 4 populations (Ainu, Bushmen, Chippewa, and Diegueño) on the basis of 19 gene frequencies.

SYMPOSIUM: ANTHROPOLOGY AND MEDICAL EDUCATION, AT THE UNIVERSITY MUSEUM

Chairman: Gabriel W. Lasker

22. Growth and medical education. Stanley M. Garn, Fels Research Institute for the Study of Human Development.

23. Comments on growth and medical education. W. W. Greulich, Department of Anatomy, Stanford University.

24. Anthropological concepts of variation in the teaching of anatomy. J. Lawrence Angel, The Daniel Baugh Institute of Anatomy of the Jefferson Medical College.

Since genetic and environmental forces produce the growing person as a biochemical interaction, human variation depends positively on the number of active genes, on their potentialities for future tissue reaction with a range of external variables including food and temperature, and on time. The resulting infinity of differences between people is so continuous that analysis has used either range versus central tendency of single traits (continuous vs. discontinuous, Sigma, V, etc.) or a type classification; multiple correlation has been too laborious.

Medical interest in the normal person has introduced from us concepts of abnormal (beyond 2 × Sigma), frequency trait classifications (e.g. arterial, visceral, or muscular variations), and bases for constitutional types (beyond the anthropologically real point). Beside these concepts the anatomy student learns practically, though on an inadequate sample, just how far the textbook individual is a myth.

Pathological variants are marked by combinations of traits which link with malfunction. Sometimes no one trait is statistically abnormal yet the combination, as in young coronary thrombosis patients, may be lethal. Masses, surface areas, and cellular reactivities of any given organ, system, or tissue vary so individually that except as a descriptive device typology must be replaced by the concept of heterogonically interacting variation between tissues and organs whose form and age changes can be measured and intercorrelated. From this standpoint sacralization of L5, a 25% weight excess of subcutaneous fat, or diastolic blood-pressure over 100 will each be abnormal when combined with deviations in other systems.

Hence in teaching we need more stress on functional measurements, on continuous variation statistics of populations and limitations of small samples, and on the individual person as an almost chance assemblage of parts custom-fitted during growth.

25. Medicine's third dimension. Benjamin D. Paul, Harvard School of Public Health.

Medicine now sees the patient in two dimensions, the organic and the psychological. This may give physicians a good picture of the patient, but if they wish to look beyond the picture and see the patient in the round, physicians will have to add another dimension to their medicine — the cultural. Cultural determinants seem to loom larger in an exotic setting than they do at home, but this is an artifact of perception. The cultural component in contemporary medicine remains elusive because we are so enmeshed in our own customs and values that these appear ''natural.'' To introduce the cultural dimension into medical teaching, we should be able to present striking cases from afar in order to arouse awareness.

We must also find suitable domestic instances of the same cultural principles, however, so that the lesson can have practical value for doctors more likely to practice in Philadelphia than Natal. Potentially rich repositories of case material for showing the influence of culture are to be found in the social class system and the series of ethnic divisions that make up America. To absorb the meaning of the cultural dimension, medical students ideally need to have direct *experience* to give depth to their understanding, acquire *concepts* to structure their thinking, and discuss *case studies* to give range to the conception of cultural variation.

26. Anthropology in relation to the practice of medicine. Wilton M. Krogman, Graduate School of Medicine, University of Pennsylvania.

27. Anthropology in medical education. Gabriel Ward Lasker.

Some functions of anthropology in medical education are suggested by the activities of anthropologists who teach in medical colleges. Human evolution, human growth, human genetics and human variation are as pertinent to anatomy as to bioanthropology. Physical anthropology integrates these subjects through its concern with both long- and short-term processes. The specially human factor of culture affects our growth as it does our evolution; to this extent there is a distinct ''human biology.'' The contribution of anthropology to medical education is not likely to come through additions to an already crowded curriculum, however. Instead it would be preferable if some of those trained as teachers of anatomy shared this ''anthropological'' point of view.

F. Demonstration of the casts of fossil men and Primates available through the American Institute of Human Palaeontology at the University Museum. Loren C. Eiseley, Department of Anthropology, University of Pennsylvania.

JOINT SESSION WITH THE AMERICAN ASSOCIATION OF ANATOMISTS CLINICAL AMPHITHEATER OF THE JEFFERSON MEDICAL COLLEGE, 1025 WALNUT STREET

28. Ancient skeletal material as a guide to health. J. Lawrence Angel, The Daniel Baugh Institute of Anatomy of the Jefferson Medical College.

On a sample of 1041 skulls from Greece cranial osteoporosis decreases from 25% incidence before 2,000 B.C. to 0% in Classical times, with later increase to 30%. Average adult life span shows a similar pattern, but body size, after a marked increase into historic times fails to show any subsequent decrease; there is marked social class stature difference in the Bronze Age.

On samples of 299 adult male skeletons and 203 females arthritis drops from 30% to 15% among males but remains at 10–12% throughout among females. Vertebral column ''arthritis'' linked with cervical or lumbar disk destruction likewise drops from 61% to 42% among males but remains at 40% among females.

This sex difference may be explained by the 5–8 years shorter female life span which perhaps reflects a relatively high childbirth mortality throughout. Temporomandibular joint arthritis fails to change. Other conditions, ranging from cancer to cholecystitis are too rare to show trends. Syphilis is absent in ancient times.

Material gathered with assistance of grants from American Philosophical Society and N.I.H.

29. The age incidence of suture closure. W. Montague Cobb, Department of Anatomy, Howard University School of Medicine.

A study of the age incidence in five-year groupings of absent, commencing and advanced closure in 9 vault and 13 facial sutures in 2,351 adult skulls of white and American Negro stock, indicates that suture closure is a variable phenomenon and that an age at which each specific suture should be found to have begun and to have completed closure cannot be categorically defined. For example, age 35 is commonly used as the standard at which the sagittal suture should have completed endocranial closure. In our series union was complete at this age in only 21.4% of male whites, 26.6% of female whites, 36.5% of male Negroes and 39.0% of female Negroes. On the other hand, in skulls of 61 years of age and older, closure was complete in but 36.5% of male whites, 40% of female whites, 45.9% of male Negroes and 49.4% of female Negroes. Closure of facial sutures, previously reported upon, begins at about the same time but does not advance to the same degree as that of cranial. Tables of incidence of closure are furnished for each adult age group according to sex and stock.

30. Differential growth of the human brain.[1] Charles R. Noback, Department of Anatomy, Columbia University.

The apparent changes in the relative sizes of parts of the developing human brain are an expression of a coordinated growth pattern. Each segment of the brain has its own specific growth rate.

An allometric analysis of the dimensions of many brain segments reveals an overall pattern of growth. A constant ratio exists between the specific growth rates of the segments of the brain. For example constant ratios can be demonstrated between the growth of the cerebellum and of the corpus callosum; the former appearing before and growing at a slower rate than the latter.

The definitive topography of the brain is the result of this process. The basis of these conclusions will be presented.

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[1] Supported by a grant from the National Institutes of Health, U. S. Public Health Service, B- 749.

31. Growth of certain human fetal cranial bones.[1] Melvin L. Moss, Department of Anatomy, Columbia University.

Data obtained from a group of 119 fetuses, cleared and stained with alizarin, ranging from 14 to 175 mm crown rump length, were analyzed with differential growth formulations. The various dimensions of all calvarial bones, and of selected splanchnocranial bones were determined. The relations existing between all possible combinations of these dimensions, as well as the relation of these dimensions to crown rump length and time (menstrual age), were determined with the following results.

The ratios of the specific growth rates of all combinations of dimensions measured showed a constant relation throughout the period of development measured. The double logarithmic plots of these dimensions, considered in relation to crown rump length and to time, showed a characteristic interphase, or change in linear slope, when the fetuses reached the 80–89 mm crown rump length range, about the end of the first trimester. The specific growth rates of these osseous dimensions decreased at this critical developmental horizon. As the interosseous ratios remained constant prior to and after these interphases, some common factor must intervene simultaneously in the development of all fetal cranial bones.

Coincident with these changes in the specific growth rates of the overlying bones, alterations occurred in the enclosed neural mass and its membranes. The possible correlation between these several phenomena are discussed.

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[1] This study was made during the tenure of a Lederle Medical Faculty Award.

32. Some problems of human evolution. William L. Straus, Jr., Laboratory of Physical Anthropology, Johns Hopkins University.

33. Emergence of permanent first molars in the monkey. Its association with other growth phenomena.[1] V. O. Hurme and G. van Wagenen, Forsyth Dental Infirmary for Children, Boston, Mass., and Department of Obstetrics and Gynecology, Yale University School of Medicine.

Analysis of longitudinal data on 26 male and 40 female macaques indicates the existence of a growth mechanism which controls, within certain limits, the schedule of initiation of the process of emergence for all the teeth of an individual animal. By utilizing standards of odontiasis developed earlier (Proc. Am. Philosophical Soc., *97:* 291, '53) and analyzing chronologic variations exhibited by different monkeys, it was found that the deviations from standards were far from haphazard for most teeth. Moderate to moderately high positive correlations exist between the eruption of deciduous second molars and permanent first molars. This finding was corroborated by using other analytical methods.

Median ages of emergence of permanent first molars ranged between 1.31 and 1.49 years, with considerably less variability in females than in males.

Normal macaques with relatively early emergence were, as a group, heavier at birth, and heavier and longer at 1½ years of age, than those with more delayed dental maturation. Also, the gestation periods were longer in those animals in which teeth erupted at earlier ages. No association was found between velocity of odontiasis and age at menarche.

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[1] Supported by a grant from the National Institutes of Health, Public Health Service.

34. The Natchez innominate bone. M. F. Ashley Montagu, Princeton, New Jersey.

Ever since its discovery in 1845 the Natchez innominate bone has occupied an equivocal position. In 1948, through the courtesy of Dr. K. P. Oakley, I submitted samples of this bone and of the associated ground-sloth *Mylodon harlani* to the Department of the Government Chemist at London. The results of the fluorine analysis did not become available till march 1954. Meanwhile Stewart had drawn attention to Wilson's 1895 study of the fluorine content of these bones, indicating that the human and mylodon bones were substantially of the same age. The results of the present study are in good agreement with Wilson's. The 1954 results show that the human bone contained 0.88% and the mylodon 0.99% fluorine, the phosphoric acid content being respectively 26.2% and 20.1%. It is concluded that the probabilities are in favor of the human and mylodon bones being of the same or similar age.

35. The pelvic remains of Australopithecus. F. Clark Howell, Department of Anatomy, Washington University School of Medicine, St. Louis 10, Missouri.

Comparison of the australopithecine pelvis with human and pongid pelves reveals its hominid nature. The earliest australopithecine, here attributed to a subgenus *(Australopithecus)*, is of Upper Villafranchian (Lower Pleistocene) age. The hip bones of this form, represented by specimens from Limeworks Cave and Sterkfontein, are characterized by: a twisted and expanded iliac blade, sigmoid curvature of the iliac crest, a true tubercle of the iliac crest, dorso-inferiorly displaced auricular region, an L-shaped auricular surface with an enlarged area, marked angulation between auricular and shank portions of the ilium resulting in a well-developed greater sciatic notch, short iliac shank, well-developed anterior inferior iliac spine, shortened ischium, relatively narrow *sulcus tuberoglenoidalis*, and superiorly situated tuberosity of the ischium.

The later australopithecine, here attributed to a subgenus *(Paranthropus)*, is of early Middle Pleistocene age. An incomplete hip bone of this form is known from Swartkrans. This was a more robust and massive creature whose overall morphology suggests its specialized and rather aberrant nature; for example, the extreme projection of the anterior superior iliac spine, the marked separation of the anterior iliac spines, the greater width of the *sulcus tuberoglenoidalis*, and the flange-like eversion and projection of the tuberosity of the ischium.

The pelvic morphology of *Australopithecus* indicates a fairly erect posture and true bipedalism, although these animals were not human. A number of truly human features are absent in *Australopithecus*, including a true supraacetabular iliac pillar, accentuated curvature of the anterior portion of the iliac crest, and approximation of anterior iliac spines. Torsion and expansion of the iliac blade were critical processes in the radiation of hominids which permitted attainment of the erect posture. Linked with these changes were expansion and postero-inferior displacement of the auricular region, accentuation of the sacral promontory and strengthening of the sacro-iliac joint. The pelvic remains of *Australopithecus* afford new evidence on the origin of hominid bipedalism and of an important stage in hominid evolution.

36. *Pelvic deformations under dynamic loading.*[1] F. Gaynor Evans, Department of Anatomy and Herbert R. Lissner, Department of Engineering Mechanics, Wayne University, Detroit, Michigan.

Tensile strain distribution, produced by dynamic loading of the ischial tuberosities, was studied in 22 intact pelves removed from the body and in 8 pelves within the body. The free pelves were tested with 39–112 inch lbs. of energy and the ones within the body with 200–400 inch lbs. of energy. The tests revealed that the pelvis behaved like an elastic body, the various ''stresscoat'' patterns arising from one or more of the following movements: (1) medial or lateral rotation of the anterior superior iliac spine, (2) lateral displacement of the acetabula, (3) medial or lateral rotation of the ischial tuberosities, and (4) various combinations of these movements. Rotations of the iliac crests creates anteroposterior tensile strain in the iliac alae, the aspect of the ala involved depending upon the direction of the rotation. Displacement of the acetabula creates tensile strain within them and the long axis of the iliopubic rami. Rotations of the ischial tuberosities causes tensile strain in the long axis of the ischiopubic rami, the aspect of the region involved depending upon the direction of the rotation. Extensive strain patterns arise from combined movements. The strain patterns indicate that the iliopubic rami function as a tension bar. Soft tissue beneath the ischial tuberosities is an excellent energy absorbing material. Linear pelvic fractures arise from failure of the bone because of tensile stress within it.

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[1] This investigation was supported (in part) by a Research Contract with the Aero Medical Laboratory, USAF, and Research Grant A-377(C4) from the National Institutes of Health.

37. *Aspects of posture correlated with bilateral osteoarthritis of the hip joint.* Charles W. Goff, Hartford, Connecticut.

Pauwels ('50) considers *split-line* patterns of the upper femur as indicating growth trajectories arising from *tensile strain* in the periosteum induced by epiphyseal growth. Evans' ('53) *''stress coat''* studies delineate *compression trajectories,* often at right angles to split-line patterns but not always so placed.

Four adult cases of bilateral, depressed osteoarthritis of the femoral head are correlated with man's erect posture. These seem to confirm the correlations of Rutishauser and Grasset ('54), Harrison, Schajowicz and Trueta ('53) as well as Hermodsson ('47) and others regarding the presence of vascular hyperplasia producing bone softening. This is followed by eburnation and depression, with osteophytes at margins of compression zone of femoral head. The constitutional aspect is emphasized through bilaterality of the X-ray findings. Usually symmetrical involvement, occurring after age 30 in hard workers, all veterans, representing a selective factor of previous good health, progressing along relatively identical lines.

Anatomic associations of the femoral head-fit with its acetabular fossa are correlated with zone of contact through split-line studies and compared with normal hips. Postural adaptations are discussed. Avascular necrosis of children, as well as of adults associated with trauma, are presented for comparison. Hereditary forms of this disorder are found in cattle, swine and sheep.

Further research is progressing, relative to indicated stress zones. This will be reported in association with Dr. Gaynor Evans at a later date.

38. Ash weight of human skeletons in per cent of dry, fat-free weight. Mildred Trotter and Roy R. Peterson, Department of Anatomy, Washington University, Saint Louis, Missouri.

Long limb bones of 10 White male cadavers and complete skeletons of 6 additional White male and one Negro male were studied. The age range is from 41 to 89 years. The cadavers or limbs providing the bones were treated differently before skeletonization. Two fat-extraction methods were tested. The dry, fat-free bones were reduced to ash, and its weight determined in per cent of the dry, fat-free weight.

An age difference is suggested in the long limb bones but not in the complete skeletons. The percentage ash weights show less variation among bones of the free limbs and skulls than among bones of the limb girdles and trunks. The appearance and weight of dry fat-free bones is not indicative of their percentage ash weights. The range of ash weights of the complete skeletons is from 54.5% to 66.9%.

The data show that the percentage ash weight of dry, fat-free bone varies among skeletons, and further, that the composition of one bone may not be a measure of the composition of other bones of the same skeleton. It is suggested that variation among percentage ash weights of bones of a dry, fat-free skeleton may be the result of a progressive change in composition which is initiated in one region and extended to other regions in an orderly sequence.

39. Degree of accuracy in estimates of chronological age of human skeletons. T. D. Stewart, Division of Physical Anthropology, U. S. National Museum, Washington, D. C.

Only occasionally has it been possible for anthropologists to check their estimates of chronological age as determined directly from skeletons. In the absence of such checks there has been considerable doubt as to the accuracy of the estimates and no way to bring about improvement. Accordingly there should be considerable interest in data from the American Graves Registration Service Group in Japan showing the results obtained by 4 observers applying current standards. The observers had had more or less anthropological training and/or laboratory experience, and were unaware that their age estimates would be used in the present manner.

The sample consists of 200 well-documented cases with a range in age from 17 years 7 months to 41 years 1 month. However, the majority falls below 25 years and concentrates in the 18–19 year period, as would be expected in any Army population. Also, of course, this is the age interval when many maturation criteria are present.

Up to the age of 25 the observers as a rule estimated age within a 3-year range (for example, 20–22). Above this age, they increased the range in accordance with their uncertainty and ultimately simply stated ''30 +.'' Comparisons of the estimates with the actual ages at death show surprisingly good agreement, but a tendency where agreement is poor for the estimates to be high.

Inter-observer comparisons yield considerable variations and suggest that the accuracy of the estimates do not depend entirely on the observer's previous training and experience.

40. Hypothalamic nuclei and endocrine glands as related to metabolism of abnormal growth. James W. Papez, Laboratory for Biological Research, Columbus State Hospital, Ohio.

Groups of nerve cells in supraoptic part of hypothalamus are connected by nerve fibers to neural part of hypophysis cerebri. They are called paraventricular and supraoptic nuclei. Their impulses activate secretions of hormones from glandular cells of anterior hypophysis. Their hormones in turn influence secretions of thyroid, adrenal and gonads, and growth of muscular and other tissues. These neurohumeral factors have normally a powerful metabolic influence on growth of organs and bodily parts. Centrally the hypothalamic nuclei receive connections from olfactory region, amygdala, ventral thalamus and bulbar (vagal) reticular formation concerned with vegetative needs and drives.

Hypothalamic nuclei and endocrine glands constitute a growth regulating mechanism under control of basal portions of central nervous system. We have come to this opinion from a study of brains and glands from feeble minded patients in whom specific, genetic defects were present. Brain, glandular, and organic defects appear to be results of organisms in cytoplasm of cells in hypothalamus, hypophysis, adrenal glands and vascular organs. Their presence alters the chemistry of growth in nerve cells, glia tissue and in secretory cells of hypophysis. The organisms produce cell damage. By-products of the organisms produce abnormal growth of tissues. Bodily and brain development is significantly affected in young individuals. This is less apparent in adults in whom the functions of brain and glands may be markedly disturbed.

41. Studies of newborn, laboratory rhesus monkeys (Macaca mulatta). James A. Gavan and G. van Wagenen, Department of Anatomy, Medical College of South Carolina and Department of Obstetrics and Gynecology, Yale University School of Medicine.

There has been a lack of reliable biological information about rhesus monkeys. Such data are needed because of increasing use of rhesus monkeys as experimental animals and experimenters' lack of familiarity with them.

This paper discusses birth weight, sitting height, and gestation for 208 newborn, rhesus monkeys. The data were collected under the direction of Dr. G. van Wagenen.

The data showed that newborn infants are heavier (by 60 gm) and perhaps longer when conceived and born in the laboratory than when born after importation of pregnant females. This may indicate that a deleterious environment during pregnancy starts the infant under a handicap.

The average values for animals conceived and born in the laboratory are: weight — 480 gm, sitting height — 196 mm, and gestation — 170 days.

Because some parents were born in the laboratory, it was possible to determine age at first conception, which is earlier than was previously thought; the minimum age for females was 2.66 and for males 3.52 years.

These 208 infants resulted from some inbreeding yet the variability indicates that experiments require more normal control animals than if pure strains were available.

Rhesus monkeys are important laboratory animals. The criteria for normality are virtually unknown and it remains for the physical anthropologist to fill this hiatus.

42. An analysis of Cook Island blood groups. Edward I. Fry, Peabody Museum, Harvard University.

One of the largest gaps in our knowledge of blood groups and types is in Polynesia. ABO data are available for Hawaii, Samoa, New Zealand, Easter and the Society Islands, but data for other groups and islands is completely lacking. Evidence gathered in 1954 on the blood groups and types of Cook Island Polynesians was presented. (The samples were gathered by the author, analyzed by R. T. Simmons and the staff of the Serum Commonwealth Laboratories, Melbourne, and most of the gene frequencies were calculated by Professor William C. Boyd, Medical School, Boston University.)

Although Shapiro found significant inter-island differences on the basis of morphological and metrical data, a χ^2 test on the island-of-origin breakdown of these data revealed no significant differences at the 5% level for the Southern Cook group. Samples were too small from the Northern Cooks for any statistical analysis.

It is believed that gene ''q'' is present as an original feature of the Cook Island genetic make-up, and is not due to White admixture, since if such a frequency resulted from Maori-White crosses, it would mean that the sample tested was approximately 40% mixed. The presence of ''σ'' in other Polynesian groups is not necessarily to be explained by racial crossing, and its presence in Hawaiians, Samoans, Easter Islanders and Tahitians may well be aboriginal. The Cook Island frequencies closely approximate those of the New Zealand Maori, thus favoring the belief that New Zealand was settled by people from the Cook Islands.

Compared with American Indians, the Cook Island Maori are higher in genes p, n, NS, Ns and $Le^{(a+)}$. American Indians are lower than Cook Island Maoris for the genes r, m, MS, K^+ and R_0. The Cook Islanders lack the genes R_2, R'' and R', all of which are present in American Indians. The view that Polynesia was settled by American Indians is therefore not supported by our data.

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RELATIVE WEIGHTS OF SOME FUNCTIONALLY IMPORTANT MUSCLES OF THE THIGH, HIP AND LEG IN A GIBBON AND IN MAN

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Did human ancestors go through a brachiating stage, or are we descended directly from a quadrupedal group? The question remains in dispute, and colors different viewpoints on the course of hominid evolutionary history and catarrhine primate taxonomy. Since fossil evidence on the problem is in general scanty and inconclusive, the divergent opinions rest mainly on anatomical comparisons of living primates with man. Straus ('49) inclines toward a non-brachiating ancestry for man, emphasizing a large number of features in which hominids are more similar to monkeys than to apes. On the other hand, Washburn ('51) has recently developed new evidence in support of tree-dwelling and brachiation as a factor in pre-adaptation to the human upright position, and against the hypothesis of a quadrupedal ground-dwelling adaptation for the ancestors of hominids. Part of this evidence is based upon the contrasting functional relationships of the bones and muscles of the pelvic limb in quadrupeds and man, as pointed out by Haxton ('47) and others. Washburn found that more strictly arboreal monkeys approached the human pattern of a relatively strong quadriceps (rectus femoris and vasti muscles) and a relatively weak hamstring group of muscles (biceps femoris, semimembranosus, semitendinosus), and a progressively greater relative strength of the hamstrings in monkey groups which spend more of their time on the ground. The ratio of the

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weight of quadriceps to hamstrings is 2/1 in man, 1.2/1 in mangabeys, 1/1 in arboreal ceropiths, 1/1.2 in vervets, and 1/2 in baboons. The first and last ratios are from Haxton ('47), the others from Washburn ('51). The ratio for baboons is the same that Haxton found for a series of typical quadrupedal mammals.

These ratios led naturally to an interest in the ratios to be found in anthropoid apes. By extending this kind of functional analysis to the locomotion of living brachiators, the evolution to the human method of locomotion may be evaluated more completely, and the fossil evidence supplemented and clarified. Accordingly, when an opportunity arose for dissecting a gibbon, muscle weights on the lower extremity were recorded for these and other muscle groups important in locomotion.

MATERIAL AND METHODS

An adult male *Hylobates lar* was donated by the Philadelphia zoo. The author is indebted to Mr. Frederick A. Ulmer, Jr., Curator of Mammals, for permission to dissect this animal. Autopsy indicated it had died from circulatory collapse after a gallstone attack. At this time the gibbon had lived 20 years at the zoo, and was estimated to be 23 years old. The animal had been less active during the last few months of life. Muscles appeared well developed, and the skeleton showed no signs of advanced ageing.

Muscles were dissected free in the fresh state and immediately weighed with their tendons on a Harvard balance. Only the fleshy parts of gastrocnemius and soleus were weighed because of their common tendon.

OBSERVATIONS

Muscle weights are recorded in table 1. The ratio of quadriceps to hamstrings is approximately 4/1, a more extreme difference from the quadrupedal condition than that found in man. The small size of gluteus maximus in relation to gluteus medius is the situation found in quadrupeds and other apes. There is no plantaris. The ratio of gastrocnemius to soleus is approximately 1.3/1 in the gibbon, as opposed to an average ratio of 1/1.5 for 10 preserved human cadavers in this laboratory. The range was 1/1.2 to 1/2.5 in this series. The soleus of the gibbon is thus by no means "dwarfed into insignificance" by the gastrocnemius and plantaris, as in Haxton's ('47) description of the quadruped situation.

TABLE 1

Muscle weights in grams

	LEFT	RIGHT
Quadriceps femoris	42.1	41.5
Hamstrings (total)	10.5	9.3
Semimembranosus	3.0	2.5
Semitendinosus	2.8	1.7
Biceps femoris	4.7	5.1
Gluteus maximus	4.2	3.7
Gluteus minimus	3.2	2.7
Gluteus medius	10.0	10.0
Gastrocnemius	...	7.2
Soleus	...	5.5

DISCUSSION

The strong quadriceps and weak hamstrings in the gibbon tend to substantiate Washburn's ('51) theory that a climbing and brachiating method of progression can be pre-adaptive to bipedal locomotion, and that human ancestors were bipedal when they adopted a terrestrial life. Gibbons are able to walk and run bipedally more easily than any other apes (Schultz, '40), and do this characteristically when traveling along large and relatively horizontal branches (Carpenter, '40). This is true in spite of their high specialization for brachiation. The upright locomotion of the gibbon has apparently led to a predominance of the quadriceps over the hamstrings greater than that in man. An arboreal life involving brachiation and bipedal locomotion can thus lead to a situation which more than duplicates the functional importance of the quadriceps in the human upright posture. In man, this muscle group must be powerful to prevent flexion of the knee joint when the weight of the body is caught upon the forward limb at the end of the stride in walking and running, and to provide much of the propulsion from the rear limb in running by extending this joint. In view of the characteristically bent-kneed gait of gibbons, a relatively strong quadriceps would seem to be necessary to prevent excess flexion at the knee joint. It should also be very valuable in leaping to higher boughs or across gaps between trees.

The characteristic use of the pelvic limb for locomotion in the upright human and brachiating gibbon both contrast markedly with that of the quadrupeds as analyzed by Haxton ('47). In such animals the limb acts mainly as a propulsive lever with its axis at the hip joint. The hamstrings act both as the principal pulling force and at the same time prevent extension at the knee joint, maintaining the rigidity of the limb during its lever action. Quadriceps is relatively weaker; acting mainly at the end of the stride, when the posterior limb is used as a propulsive strut.

The muscles of the hip joint of the gibbon reveal no particular trend toward the human situation. The gluteus maximus remains a weak abductor, in keeping with the long, straight ilium, rather than the powerful extensor of the thigh found in man (Elftman, '54). In this it is quite similar to quadrupeds (Haxton, '47), monkeys, and other apes (Kohlbrügge, 1897). Gluteus medius is the strongest of the gluteal muscles, also as in quadrupeds and monkeys. It is the principal muscle in preventing excessive flexion of the thigh on the hip when the weight of the body is placed upon the forward limb, a function taken over by gluteus maximus in man.

The large gastrocnemius of the gibbon indicates that its action in flexion of the knee joint is important in normal locomotion, as in the quadrupeds. The absence of the plantaris verifies the findings of von Bischoff (1870) and Kohlbrügge (1897). As in man, this muscle is either absent or very weak in other anthropoids, according to these authors, but may be substantial in monkeys. The one-joint soleus is of considerable size in the gibbon, indicating increased importance of plantar flexion in locomotion for this animal. The many short, multipenniform fibers of this muscle give it a powerful action over a short range of motion. This would give the gibbon a strong backward thrust on the rear foot near the end of the stride, as in man.

From the above, it is indicated that gibbon brachiation and bipedal locomotion can be pre-adaptive to the human situation in the thigh muscles, that pre-adaptation is foreshadowed in the muscles of the leg, but the hip muscles remain virtually the same as in quadrupeds. The gibbon does not show any trend toward the major locomotor change Hooton ('46) describes as bound up with the assumption of the erect posture and biped gait on the ground, the rearrangement in the pelvis and gluteal muscles. The limb musculature continues a trend toward the human situation found in the more arboreal monkeys, however. This indicates that continued arboreal life is pre-adaptive to brachiation and thence bipedal locomotion, while characteristic ground-dwelling in quadrupedal primates leads to a different functional arrangement of bones and muscles of the hind limb.

The analysis of muscle action and its relationship to locomotion in different animals needs to be extended beyond the relatively crude level represented by this and other studies using gross weight of the muscles. Muscle weight is useful in comparing relative strength of muscles if their internal structure is similar for the animals compared. In order to test the validity of such studies and to extend their usefulness, comparative studies of the fiber structure, attachments, strength and mode of action of muscles in different groups of animals are needed.

SUMMARY

1. Muscles of the lower extremity of an adult gibbon were weighed.

2. Ratios of muscle weights are approximately as follows: quadriceps to hamstrings, 4/1; gluteus medius to gluteus maximus, > 2/1; gastrocnemius to soleus, > 1/1.

3. The ratio of quadriceps to hamstrings tends to support the idea of brachiation and bipedal locomotion as being preadaptive to the human type of upright position. That of gastrocnemius to soleus is also in this direction, but not so markedly. That of the glutei is virtually the same as in quadrupedal monkeys.

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LOWERING OF PELVIC INLET INDEX IN THE ONTOGENY AND PHYLOGENY OF MAN

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ONE FIGURE

In human embryology a certain resemblance has been observed between the ovum as it splits and the ovum of reptiles, and it is also known that the human embryo contains a rudimentary gall bladder, neural tube, gills, webbed feet, the toes connected by traces of mucous membrane, a tail, os coracoideum, the third eyelid and other organs which disappear later. These observations on the embryonic development of man, in view of Haeckel's theory of recapitulation throw a certain light on man's earliest genealogy. Though there are objections in reference to biogenetic law (de Beer, '40), it would be desirable to see if there are changes in ontogeny which, judging by the paleontological data, existed in the phylogeny of man.

Remains of quadrupedal Dryopithecinae of the Miocene and remains of Australopithecinae of the Pliocene suggest, besides others, that the origin of man is connected with quadruped creatures and the upright posture was the result of evolution. In quadrupedal mammals the characteristic shape of the inlet is dolichopellic (mean inlet index > 100.00). It may be supposed that in the phylogeny of man, the pelvis was flattened, which found expression in the lowering of the inlet index. The aim of this study was to investigate whether in the ontogeny of man there exists an analogous change in shape of the pelvis. In spite of the fact that such an investigation would involve a great deal of laborious work, I was encouraged by the results obtained from external measurements of the pelvis by Scammon and Calkins ('29), who observed that at a certain stage in embryonic development, the pelvis increased more in the frontal than in the sagittal plane, which provides evidence of a gradual flattening of the pelvic inlet.

MATERIALS AND METHODS

Investigations were carried out on 500 human fetuses, which included 239 females of 11.6 cm to 58.5 cm in length and 261 males of 9.0 cm to 58.0 cm in length. This material was sent by I Women's Clinic and other Obstetrical Departments in Warsaw in 1950 and 1951 to the Department of Pathological Anatomy of the Warsaw Medical Academy. The author wishes to thank Professor L. Paszkiewicz, Director of the Department of Pathological Anatomy, for permission to study the given material.

In view of the fact that changes in the proportions of the body occur with the process of decay or by the drying up of the body or with the use of preserving agents (Scammon and Calkins, '29), I measured the fetuses without preserving them in each case within 48 hours from the respective birth or death. The measurements were taken in the usual anatomopathological sections. After straightening out the fetus, the length was measured from the crown of the head to the lowest point of the heel. From the total length of the fetus, I calculated their age using the well-known formula for this purpose. After opening the abdominal cavity, I prepared the inlet and then measured the transverse and antero-posterior diameters. The measurements were taken to the nearest 0.1 mm by means of a slide rule. Each measurement was taken three times and the mean of the three measurements was taken as the final one.

After completion of measurements, the data thus obtained were tested by the analysis of the variance (Fisher and Yates, '48) in the Mathematical Institute of S.G.G.W. in Warsaw. I wish to thank Professor Z. Nawrocki who is director of the Institute, and others for their help and most welcome advice.

RESULTS

The results of the investigations are as follows:

TABLE 1

Length in millimeters of the antero-posterior and transverse diameters of the inlet in 500 fetuses[1]

LUNAR MONTH	LENGTH OF FETUS IN CM	239 FEMALE FETUSES			261 MALE FETUSES		
		No.	a-p diameter	Transverse diameter	No.	a-p diameter	Transverse diameter
IV	9.0–16.9	20	8.80	8.76	21	7.74	7.67
V	17.0–25.9	40	13.65	13.61	37	12.80	13.58
VI	26.0–30.9	42	17.58	18.30	42	17.74	18.28
VII	31.0–35.9	40	21.29	22.32	41	20.82	22.19
VIII	36.0–40.9	21	24.43	25.43	40	24.87	26.32
IX	41.0–45.9	24	27.99	29.59	26	28.99	29.71
X	46.0–58.9	52	33.79	35.27	54	33.48	35.67

[1] In the following tables, the statistically significant differences have been marked: * when significant at between the 2% and 5% levels, ** when between the 2% and 1% levels, and *** when significant at the 1% level or less.

By dividing the antero-posterior diameter by the transverse diameter and multiplying by 100, I obtained the inlet index separately for each of 500 fetuses. The use of indices is here particularly useful since it enables us to eliminate the factor of general growth.

TABLE 2

Inlet index in 500 fetuses

LUNAR MONTH	239 FEMALE FETUSES			261 MALE FETUSES		
	No.	Index	Range	No.	Index	Range
IV	20	100.39	80–121	21	100.87	83–126
V	40	100.26	78–138	37	94.25	70–109
VI	42	96.05	76–117	42	97.03	60–128
VII	40	95.39	70–116	41	93.79	73–110
VIII	21	96.03	79–109	40	94.46	77–112
IX	24	94.58	83–110	27	97.55	77–119
X	52	95.78	72–121	54	93.84	79–118

Table 2 shows certain differences in the indices with regard to age and sex. To test which of these are statistically significant we shall perform an analysis of variance. The analysis is carried out as follows. First, the total variance for all values of the indices is calculated. This is expressed as the sum of two variances, the first being the variance between the 14 age-sex groupings, and the second being the residual or within-cell variance. The within-cell variance arises from inherent biological variation and from errors of measurement. We thus obtain table 3.

TABLE 3

Analysis of variance of inlet indices in 239 and 261 male fetuses in the last seven lunar months of pregnancy

SOURCE OF VARIANCE	SUM OF SQUARES	DEGREES OF FREEDOM	QUOTIENTS S_1 and S_2	e^{2z} (= F RATIO)
Age-sex groupings	2438.00	13	187.538	
Residual	45984.33	486	94.618	1.98
Total	48422.33	499		

Since the value for e^{2z} is 1.98 and is therefore greater than the corresponding 5% critical value, the 5% significance value for the F ratio with 13 and 486 degrees of freedom is 1.77. We may therefore examine, by means of the t-test, whether the differences between the mean value of the indices are statistically significant.

TABLE 4

Significance of the differences between the mean inlet indices in 239 female fetuses in the last seven lunar months of pregnancy[1]

	IV	V	VI	VII	VIII	IX	X
IV	....	0.049	1.049	1.885	1.433	1.972	1.780
V	0.130	....	1.960	2.240	1.613	2.262	2.188
VI	4.340	4.211*	....	0.308	0.006	0.590	0.131
VII	5.002	4.873*	0.660	....	0.246	0.401	0.194
VIII	4.356	4.227	0.019	0.646	....	0.499	0.099
IX	5.808*	5.679*	1.468	0.810	1.452	....	0.501
X	4.605	4.476*	0.265	0.379	0.249	1.205	....

TABLE 5

Significance of the differences between the mean inlet indices in 261 male fetuses in the last seven lunar months of pregnancy[1]

	IV	V	VI	VII	VIII	IX	X
IV	....	2.493	1.478	2.714	2.446	1.165	2.810
V	6.627**	....	1.270	0.210	0.098	1.327	0.194
VI	3.842	2.785	....	1.518	1.195	0.234	1.593
VII	7.084***	0.463	3.246	....	0.314	1.541	0.268
VIII	6.411**	0.218	2.567	0.675	....	1.259	0.306
IX	3.325	3.302	0.517	3.759	3.086	....	1.596
X	7.030***	0.410	3.188	0.054	0.621	3.705	....

[1] Entries below and to left of diagonal are observed differences between age averages. Entries above and to right of diagonal are values of t computed from the differences.

TABLE 6

Significance of the differences between the mean inlet indices in 239 female and 261 male fetuses in the last seven lunar months of pregnancy

MONTHS	IV	V	VI	VII	VIII	IX	X
''t'' empirical	0.159	2.711	0.462	0.740	0.599	1.077	1.027
Differences	0.483	6.015***	0.981	1.600	1.570	2.968	1.942

DISCUSSION

To facilitate discussion of the obtained results they are presented graphically by figure 1.

We see in the female fetuses (table 4) a statistically significant difference between the means for months IV and IX, V and VI, V and VII, V and IX, and V and X. In the male fetuses (table 5), a significant difference occurs between the means for months IV and V, IV and VII, IV and VIII, and IV and X. Ingeneral, we may say that in female fetuses the mean inlet index in the IV and V month is 100.33, while between the V and VI month it falls and then remains without any important aberrations more or less about the value 95.57 until the end of the fetal period. In the last 5 lunar months of pregnancy this is the common mean (weighed) of the inlet indices in the female fetuses. In male fetuses the inlet index is 100.87 in IV month, while between the IV and V month it falls, remaining to the end of the fetal period without any important aberrations more or less about the value 95.15, the weighed common mean for the last 6 lunar months of pregnancy. In the male fetuses the high index in the IV month can partly be explained by the poor formation of sex characteristics at this period, one of which is the low value of the inlet index in the male sex. In the IV month not only tertiary sex characteristics, such as those of the pelvis, are poorly developed, but secondary as well, especially at the beginning of the IV month, with the result that macroscopic determination of sex on the basis of external observation remains frequently very difficult and uncertain. Besides that, in the IV month, 6 out of 21 male fetuses were from 9.0 cm to 11.0

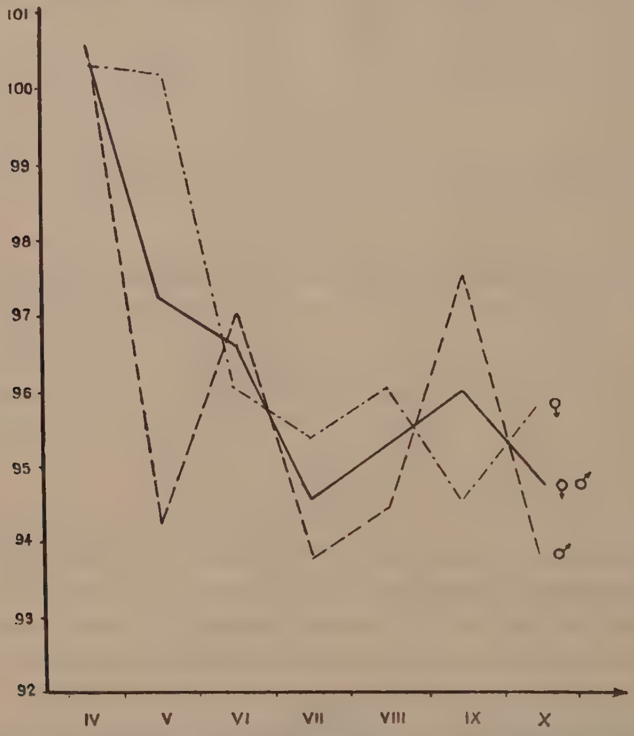

Fig. 1 Mean inlet indices in 239 female and 261 male fetuses in the last 7 lunar months of pregnancy measuring from 9.0 cm to 58.5 cm in length.

cm in length, while the youngest female fetus was 11.6 cm in length which would influence the height of the mean inlet indices. In the V month the much longer retention of a high inlet index in the female sex may partially be explained — of course with recapitulation in mind — by philogenetic natural selection confined to that one sex. During phylogeny, females with greatly changed pelves were unable to produce offspring and thus to pass on these characteristics before all the elements in birth had adapted themselves to the changed birth canal.

After these remarks, we will now speak of the fetuses of both sexes together. In the early period of ontogeny, the mean inlet index is 100.63 which is very near to the inlet indices in the majority of quadrupedal mammals which have a pelvis of dolichopellic shape. In the V month the index falls; then from the VI month onwards to the end of prenatal development, it remains about 95.36. This figure represents a pelvis of recent man with completely upright posture (Krukierek, '54). In the earlier period of ontogeny where we find high inlet indices similar to the high indices found in quadrupedal mammals, there is marked difference between the sexes. Fetuses of the female sex have higher inlet indices than the male, just as female quadruped mammals have higher inlet indices than the males. As the pelvis became more platypellic, the difference in the fetuses became less marked, which also holds for modern bi-ped man (Krukierek, '51). It is worthy of note that the flattening of the pelvis in the fetus takes place along with other changes in the proportions of the body. The lumbar region of the spine becomes thicker, the promontorium becomes more marked, the hind limbs become longer than the fore ones, the radical transformation of the foot is completed and the fetus clearly acquires human characteristics (Burtscher, 1877; Bonnet, '07; Scammon and Calkins, '29; and Brandt, '49). In the light of the law of recapitulation, the lowering of the mean inlet index in fetuses of both sexes from 100.63 to 95.36 (i.e. changing the shape of the pelvis to platypellic) may therefore be regarded as the reflection in ontogeny of the changes accompanying man's adoption of the upright posture in phylogeny. In the fetus the change refers to those parts of the body whose recapitulation may have been subject to less change than others, since they play no part in preserving the life of the fetus in the conditions within the womb. The lowering of inlet index in ontogeny together with other changes of proportion and in addition to the paleontological data, provide evidence in favor of the biogenetic law.

SUMMARY

In 500 human fetuses from 9.0 cm to 58.5 cm in length, the author measured the antero-posterior and transverse diameters of the pelvic brim.

After calculating the indices of the inlet and analyzing the variance, the author showed that in the IV lunar month of pregnancy the mean inlet index of the fetuses is 100.63 which is very near to the high inlet indices of the quadrupedal dolichopellic mammals. In the V lunar month the mean inlet index falls and from the VI to the X lunar month of pregnancy is 95.36. The lowering of the inlet index in ontogeny indicates, in the light of biogenetic law, that there were changes in posture during the phylogeny of man.

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FURTHER REMARKS ON THE RELATIONSHIP BETWEEN "MEGANTHROPUS" AND AUSTRALOPITHECINES

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ONE FIGURE

In a recent paper (Robinson, '53) an attempt was made to show that the specimens described as *Meganthropus palaeojavanicus* and *M. africanus* appear to have a similar assemblage of characters to that found in the australopithecines from South Africa. Both of the species mentioned above are, unfortunately, known only from very scanty remains and absolute certainty of their affinities must await the time when more complete remains are known. In the case of the Javan form another mandible has recently been found (Marks, '53) which, while useful, is too poorly preserved to add very significantly to our knowledge.

In a subsequent paper (Robinson, '54) the name *Meganthropus* was sunk. *M. palaeojavanicus* has been transferred to the genus *Paranthropus,* retaining its specific status, while *M. africanus* has been referred to the genus *Australopithecus.* In the latter case the known material is too scanty to enable a specific determination to be made, hence this specimen has been referred provisionally to the only species at present known of the genus, *A. africanus.* It cannot be distinguished satisfactorily from the latter, but it is clearly realised that with fuller material the two might not prove to be con-specific.

The statement of affinities expressed in the above summary has been adversely criticised by Remane ('54a and b) and rejected for the Javan specimen by von Koenigswald ('53/4, '54). The present paper is concerned to inquire into the validity of the criticisms made by these authors.

The East African Prehominid

Remane first attempts to show that the Laetolil form belongs to the genus *Meganthropus* and then, from the combined East African and Javan evidence, suggests that some discrepancies have to be accounted for if the above classification is followed. The following sentence (Remane, '54a, p. 4) sums up his reasons for referring to Laetolil form to "Meganthropus": "The genus *Meganthropus* was based on a fossil hominid from Java *(Meganthropus palaeojavanicus* von Koenigswald), and the African 'Meganthropus' resembles this form in the *structure and dimensions of the premolars* (italics mine) — but only the lower premolars are known in *M. palaeojavanicus,* not those of the maxilla, which are only known in *M. africanus.*" It is difficult to see how this statement can be held to indicate affinity between the two forms. It rather serves to show that, not having comparable parts of the two forms, it is not legitimate to say that they resemble each other in structure and dimensions and therefore belong to the same genus. On the other hand, comparable parts of australopithecines are known in reasonable quantity and so direct comparison with them are possible.

When such direct comparisons are made one finds that while the teeth of the Laetolil specimen differ from the *Paranthropus* homologues, they can be matched in size and structure among the specimens from Sterkfontein. As far as lengths and breadths are concerned, not only do the dimensions of the East African teeth fall within the observed ranges of the Sterkfontein equivalents, but in Sts. 12 we have a specimen in which P^3 and P^4 have almost identical dimensions to those of the East African form (Robinson, '53). Similarly, the structure of the teeth of the latter can be duplicated in the present Sterkfontein collection. Remane has drawn attention to some differences between the latter specimens and the East African one. He says that there is no "antero-inferior extension" of the buccal surface of the crown of P^3 in the former type; but this is based on a misunderstanding. In my figure ('53) three different teeth were illustrated in different views and the caption noted that two of these were from the left side, but ommitted to say that the other was from the right side. Remane assumed this one also to be from the left side, as a result of which it appeared to have the extension in just the opposite direction to that of the East African homologue. This was pointed out in correspondence and in his subsequent paper ('54b) the error is noted in a footnote.

A further statement is made that the main cusp of P^3 is lower on the Sterkfontein specimen. Of 4 Sterkfontein specimens which are least worn, the vertical buccal height varies from 9.3 to 9.8 mm as compared with 10.4 for the East African specimen. This difference is much too small to have special significance. Remane also suggests, in his second paper, that the australopithecine premolars are more molarised than are those of the Laetolil form. The first upper premolar is not significantly molarised in either of the two groups of australopithecines. P^4 does show a slight tendency to molarisation, if by this is meant the relative increase in size of the talon as compared to the rest of the crown. If one measures the distance in the midline from the mesial margin to the deepest part of the posterior fovea, and that from this point to the distal crown margin, the ratio between the two serves as an index of the degree of molarisation. For P^4 from East Africa this ratio is 2.1, the measurements being taken from Remane's drawing. This index can be determined for three Sterkfontein specimens: 1.9, 2.4 and 3.0. From this it seems clear that in this character also the Laetolil specimen falls within the observed range of variation of the Sterkfontein form.

The roots of P^4 also fail to provide differences between the two forms. Attention should here be drawn to an apparent contradiction in my own writings on this subject. In the paper on "Meganthropus" it was stated that, "in *M. afri-*

canus, Plesianthropus and *P. robustus* the known specimens of P^3 appear to have three roots but as all are *in situ* there can be no certainty on this point.'' In a recent paper on the taxonomy of the prehominids ('54) it was pointed out that *Australopithecus,* with one known exception, has a single buccal root while in most cases *Paranthropus* has two. The change resulted from the acquisition of several, new, isolated specimens of this tooth from Sterkfontein as well as the dissecting out of the buccal roots of the specimens *in situ* in the course of work on the taxonomic paper. It was found that all but one of the roots of the Sterkfontein specimens which appeared to be double were in fact single, but with a groove running down the buccal face. Therefore, although almost all of the specimens from this site have a single buccal root on P^3, the one specimen which happens to resemble the Laetolil specimen most in size, has, like the latter, two quite distinct buccal roots. P^4 in this specimen has a single buccal root, as have the few other specimens known. In this they agree with the Laetolil specimen.

In view of the above it seems impossible to find any valid grounds either for excluding the East African specimen from the genus *Australopithecus,* or for referring it to the same genus as the Javan form — whether this is regarded as *Meganthropus* or *Paranthropus.*

The Javanese Prehominid

Remane ('54b) has expressed an opinion about the possibility of the Javan form being related to the South African ones; he concludes that this is unlikely because of a number of australopithecine characters which are not known in the Javan species. These are: (a) a strong tendency to molarisation in the premolars, and, more especially, in the first milk molars, (b) small incisor size.

In respect of the first point, attention must here be confined to comparisons with the australopithecine mandibular teeth as the maxillary teeth are not known in the case of the Javan form. P_3 shows slight, if any, tendency to molarisation in either of the forms being considered. P_4 does show some tendency to molarisation in *Paranthropus*, more so than in *Australopithecus*. Using the same method that was adopted in the case of the maxillary premolars earlier in this paper, the following ratios were found in a series of *Paranthropus* teeth: SK.25, 1.85; SK.23, 1.89; SK.826, 1.84; SK.9, 1.70; and SK.830, 1.87. Measuring on the cast — which is legitimate as a ratio is being determined — the corresponding value for the Javan form is 1.85. The latter value is obtained when the measurements are so made as to minimise the degree of molarisation. This can be done because the fissure forming the bottom of the posterior fovea runs at an angle across the crown. If the measurement is made from that part of the posterior fovea fissure which is best developed, then the ratio is 1.66. It is therefore plain that P_4 of the Javan specimen shows a comparable or higher degree of molarisation to that found in the *Paranthropus* homologue, certainly not less. Neither of the upper nor the lower first milk molars are known in the Javan specimen, hence no comparisons can be made regarding their degree of molarisation.

Regarding the second point; no incisors are known of the Javan form, nor is the incisor region preserved in the type specimen. However the latter region is largely present in the new mandible which has been briefly described by Marks. It seems clear enough from the preserved roots of the left central and lateral incisors (Marks, '54, plate 2) that in this specimen, at least, the incisors were of the same size, and situated in the fashion of, the *Paranthropus* homologues. This newer evidence removes the necessity to discuss Weidenreich's reconstruction of the type jaw, which Remane regards as being probably accurate. It seems clear enough from the figures and description given by Marks that Weidenreich's reconstruction is not accurate, but for full confirmation of this we must wait on the more detailed study of the specimen.

Remane's final point, made only in passing, is that the lingual cusp of P_3 is small and lower than the buccal one in

"Meganthropus." This is also the case in the Swartkrans P_3. I have tried to show in a number of publications, including that on the "Meganthropus" question, that the structure of P_3 in this specimen is typically australopithecine and resembles the *Paranthropus* condition in particular. The main features of the australopithecine P_3 are: relatively robust crown, buccal cusp well developed and centrally placed on the buccal half of the crown, lingual half of the crown assymetrical with the lingual cusp always present but smaller than the buccal one, anterior fovea less extensive than posterior one, foveae either separated or joined by a longitudinal fissure, distolingual angle of crown protuberant producing asymmetry, usually strong, of the lingual half of the crown, root system well developed and usually having an exaggerated version of Tome's root form but sometimes also two more or less well separated roots. Although the *Sinanthropus* homologues resemble the australopithecine ones to an appreciable extent, the two types may be distinguished with ease. This is not the case with the Javan and Swartkrans teeth.

In Part III of his '53/54 paper, von Koenigswald remarks that "The outlines and pattern of the lower premolars and first molar is, however, not as similar as Robinson, judging from casts only, is inclined to assume." In the paper on "Meganthropus" (Robinson, '53), my remarks on the morphology of the Javan jaw were based on *both* casts and examination of the original remains; the latter was made possible during my visit in the summer of 1951 to Professor von Koenigswald's laboratory when he very kindly placed his material at my disposal. The statement is further made ('54b) that the crown outline of P_3 is more oval in the australopithecines and more angular in the Javan form. This is hardly correct, as is shown in figure 1. If a tracing is made of diagram (d) ("Meganthropus") and superposed on (b) (Swartkrans), the outlines will be found to be virtually identical. As may readily be observed from the figure, there is a greater range of variation exhibited in (a), (b) and (c), all from the Swartkrans site, than there is between (d) and (b). The fissure pattern is variable — the figure shows this clearly — so that the fact that the "Meganthropus" one is not identical with the others shown is of no significance. Furthermore the fissure pattern of the "Meganthropus" P_3 is duplicated in that from the left side of the adult Kromdraai specimen of *Paranthropus*. The Javan tooth cannot be regarded as essentially different. The premolars of the latter form fall within the observed ranges of variation of the *Paranthropus* homologues — as has previously been demonstrated — in absolute size, relative size, degree of molarisation as well as in structure of the crowns. von Koenigswald feels that "the two-rooted second premolar [australopithecine] must already be regarded as a sign that it belongs to a different category." This suggests that the Javan specimen

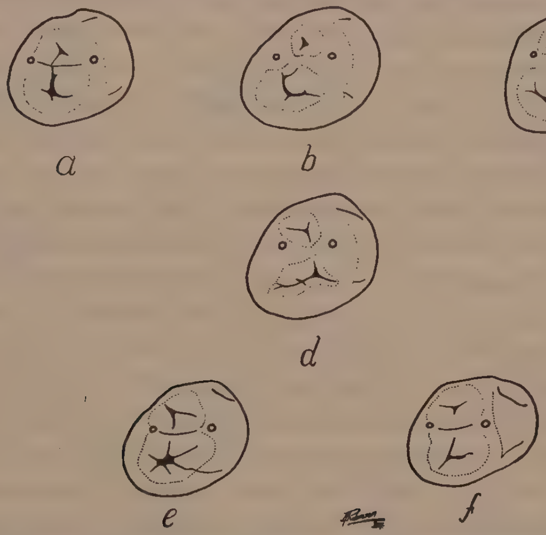

Fig. 1 Comparison of crowns of P_3 of some prehominids.

(a) Swartkrans (SK.831)
(b) Swartkrans (SK.100)
(c) Swartkrans (SK.55b — reversed)
(d) So-called "Meganthropus" type, Sangiran
(e) Sterkfontein (Sts.51)
(f) Sterkfontein (Sts.52b)

Note the greater similarity between (b) and (d) than between (a), (b) and (c). All but (a) have high trigonid crests. All tracings to same scale with camera lucida.

is regarded as having a single root, which may well be the case. However, as in the case of P_3, the root is narrow on the buccal side but wider on the lingual one; the difference being greater in the case of P_4. But P_3 does not have a single root *sensu stricto*, because a mesiolingual cleft is present indicating the incomplete fusion of two roots. The breadth of the lingual face of the P_4 root suggests that such a cleft is also present in this case. In *Paranthropus* all the known specimens of P_4, where the roots are visible, have two separate roots. In *Australopithecus* (from Sterkfontein) one isolated specimen has two roots very closely applied to each other, one specimen *in situ* clearly also has two roots but in another (Sts. 52b), in which the buccal aspect of the alveolar region is damaged in the relevant area so that the buccal portion of the root can be seen clearly, the buccal face is single, but a lingual cleft is present. This condition is similar to that probable in the Javan specimen. Furthermore, it is abundantly clear in the australopithecines that the upper and lower premolar root is reducing. Also, P^3 in *Paranthropus* is usually three-rooted while in *Australopithecus* it is usually two-rooted, thus showing considerable variability in premolar root number in the group as a whole. The condition of the root in the Javan form can therefore not be held to exclude it from the latter group. It is also interesting to note that P_4 of the specimen which is currently named *Pithecanthropus dubius* is two-rooted (Weidenreich, '45) which is a significant fact, whether one agrees with von Koenigswald's referring it to the above genus or whether one regards it as belonging to the same group as the Javan specimen under discussion. Particularly in the case of the dentition it seems to me essential to realise that one is dealing with a dynamic process of change in the prehominids and euhominids, not a series of static conditions.

One of the important distinctions, in the opinion of von Koenigswald, between the australopithecenes and "Meganthropus" is "the basic pattern of the premolars and the first molar, which still have an undivided ridge between protoconid and metaconid, conditions which I could not detect in any of the South African species." As all the teeth in the type specimen are worn it is not known whether these ridges are completely undivided, that is to say, of the same height all along as the tips of the two cusps concerned. In the case of the premolars one can say that there is a fairly high barrier between the anterior and posterior foveae. Such a condition is certainly present in the australopithecines, though the opposite condition with little or no barrier also occurs. As examples, high or moderately high trigonid crests are present in *Paranthropus* on SK.55b (P_3) and SK.25 (P_4) and in *Australopithecus* on both teeth in Sts.52b and TM.1523 (P_4). This is clearly shown in figure 1. (a) has a very low trigonid crest which is cut by a fissure but all the other australopithecine teeth illustrated have high trigonid crests of the sort found in the Javan tooth.

In the case of the first lower molar, the crown of the Javan specimen is so worn that practically nothing is left of the crest. In this case one can say no more than that there was at least a slight barrier between the anterior fovea and the central fossa. In *Paranthropus* a slight barrier does occur in this position and in one instance (SK.25) there is a moderately high one. Clearly a high crest is not characteristic of the Swartkrans M_1 — but then we do not know that it was of the Javan form either. However a well developed crest does occur on dm_2 in some, but not all, of the *Paranthropus* specimens from Swartkrans. Detailed comparisons of the second lower milk molar from Sangiran with that of the australopithecines cannot be made now as the former specimen has not yet been described in detail. It may be noted, however, that in some of the Swartkrans specimens a rudimentary cusplet is present similar to that described for *Sinanthropus* by Weidenreich ('37) as a paraconid.

The sagittal crest which is present in some of the specimens from Swartkrans is regarded by von Koenigswald as being a remarkable parallel to the pongid condition and — with some other features — leads him to suggest that the australopithecines were anthropoidal hominids forming a specialised sidebranch on their own. The feature is also regarded as a "significant difference from the Hominidae." It is stated that "Two specimens of the large *Plesianthropus* from Swartkrans have a well developed sagittal crest which is not found in the smaller species." *Plesianthropus* has now been sunk (Robinson, '54) as a generic name, but before that it was only known from Sterkfontein and is an example of the smaller form of australopithecine, which also occurs at Taungs and Makapan. Although no actual sagittal crest has been found in the small form, the original Makapan occipital fragment very strongly suggests that this structure did sometimes occur in this type (Robinson, '54b and c). The sagittal crest in the australopithecines is not a close parallel to the pongid condition. In the latter a well developed nuchal crest is almost invariably associated with a sagittal crest, while all the available evidence points clearly to the fact that this was not so in the australopithecines. SK.49 from Swartkrans is a specimen in which a sagittal crest is present in the region of the bregma, but is not present in the region of the lambda, nor is there anything which could be called a nuchal crest on the occiput. This evidence is supported by that from SK.48 (Robinson, '54c).

The sagittal crest is not intrinsically determined as such (Washburn, '47) but is a resultant of a complex of factors. The immediate cause, which is not primarily dependent upon body size, is a combination of *relatively* large temporal muscles with *relatively* small neurocranium. If, in association with this, partial or complete quadrupedality also occurs, so that the occiput passes fairly high up the back of the skull and the neck muscles are relatively well developed — as in some great apes — then the temporal and nuchal musculature will be separated by tri-radiate bony crests, the sagittal and nuchal crests. If, on the other hand, the conditions which give rise to a sagittal crest are combined with a bi-pedal posture, when the occiput is situated in a relatively low position — that is to say, it does not pass high up the back of the skull — and the nuchal musculature is not so heavily developed, then a nuchal crest does not occur even though a sagittal crest occurs anteriorly. The latter conditions exist in the australopithecines, or at least in *Paranthropus*. There is no reason why similar conditions should not have existed in the ancestors of the euhominids. If one reflects that euhominid ancestors must have had relatively small brains and that early euhominids were relatively robust creatures with relatively robust muscles, it is clear that sagittal crests of the australopithecine type may very easily have occurred in such ancestral forms.

This leads on to the question of sexual dimorphism in early hominids. von Koenigswald considers that the designation of two of the Swartkrans skulls with sagittal crests (SK.46 and SK.48) as females is "quite improbable," his reasoning presumably being that crested forms are most likely to be males. The only fully mature skulls from Swartkrans which have the relevant region preserved (3) all have sagittal crests. The possibility therefore does exist that crests were characteristic of adults of both sexes. Moreover, careful study of the permanent dentition (270 specimens, 202 measured) of the Swartkrans form has shown that sexual dimorphism is so slight (in the teeth at any rate) that it can only be demonstrated statistically and in the case of some tooth types only. It is fairly clear in the case of the breadth of the maxillary canines. SK.48 has a slightly worn upper canine *in situ* and in a frequency distribution its breadth value (unaffected as yet by wear) falls in the modal class of the female section of the clearly bimodal distribution. In spite, therefore, of the presence of a well developed sagittal crest, this skull must be regarded as that of a female. This also supports the suggestion that mature adults of both sexes normally had sagittal crests in the Swartkrans form, but much more evidence is necessary before this suggestion can be regarded as proven. The smaller *Australopithecus* appears to have had a slightly greater degree of sexual dimorphism, though still only of a low order. The small degree of dimorphism does not favour

Hooijer's suggestion (quoted by Remane, '54a) that the Javan "Meganthropus" may have been a male *Pithecanthropus*. The resemblance to *Paranthropus* is much too detailed in the first place and in the second the only early hominids which are well known (australopithecines) do not appear to exhibit what seems to be the generally expected relatively high degree of sexual dimorphism.

A further point made by von Koenigswald is that "There is not a single feature in the original *Meganthropus* jaw fragment which cannot be matched with other primitive human jaws."

If 'human' is used here in the same sense as euhominid, then this statement can surely not be supported. One of the most obvious features of the mandible in question is its general massiveness. This cannot be matched in any known euhominid, but it can among the *Paranthropus* specimens from Swartkrans. (*Gigantopithecus* cannot be considered in this connection because its affinities are uncertain and if it should turn out to be hominid it surely cannot be euhominid.) Almost without exception the characters of the "Meganthropus" specimen can be matched more easily and accurately among the known australopithecines of South Africa than they can among known euhominids. For example it would at best be extremely difficult to match the size of the teeth, especially the molar, among those of euhominids. If this could be done it would only be with extreme variants, while the dimensions, of the molar especially, fall very close to the *mean* values for the Swartkrans *Paranthropus*.

The new jaw from the Sangiran area sheds some added light on this matter. The dimensions given by Marks show that the type jaw of 1941 is not abnormally large. The dimensions of the molars suggest that — as may have been predicted — molar size increases from M_1 to M_3. These figures also show that these teeth are larger than those of the *Pithecanthropus* B mandible — indeed they are larger than the *maximum* values known for *Sinanthropus* — but fall within the observed range for *Paranthropus* with the exception of the breadth of M_2. This dimension is 0.7 mm less than the minimum now known in *Paranthropus* from Swartkrans. However, it must be remembered that in the case of M_1 and M_2 Mark's figures represent the dimensions at the neck of the tooth as the crowns are missing. The crown dimensions would therefore be greater and would then undoubtedly fall in the observed *Paranthropus* range.

CONCLUSION

In the light of present knowledge it is quite clear that the australopithecines are not pongids. It is also fairly clear that they should not be included without distinction among true men (euhominids). They are a group on their own but are very closely related to the euhominids. In the relatively small neurocranium, flat nasal region and relatively heavy face they resemble the pongids. In their erect posture with the concomitant pelvic structure and the predominantly euhominid-like dentition, they resemble the euhominids, but differ from the latter in the massiveness of the post-canine dentition, the structure of the nasal cavity floor and the massiveness of the mandible. There are naturally other resemblances and differences, but the above serve to show the major divisions. A number of features, especially dental ones, form with those of the euhominids, a continuous evolutionary series — particularly if *Telanthropus* is also taken into account. This is especially clear in the evolution of the upper and lower premolar roots as well as absolute crown size of the whole dentition and changes in relative crown size along the tooth row. In this connection von Koenigswald's 'brain-molar coefficient' serves only to show that the prehominids are not euhominids. This we already appreciate clearly. It certainly does *not* show that an australopithecine could not have been ancestral to euhominids. The teeth of the australopithecines were reducing in size (absolute and relative). It is clear that euhominids must have descended from a small-brained ancestor. Hence, if an australopithecine continued the observed tooth reduction and also increased its brain size, a euhominid condition would have resulted, complete with appropriate 'brain-molar coefficient.'

On the other hand it is clear enough that neither *Paranthropus* nor *Australopithecus* could have been ancestral to euhominids — which is one of the strong reasons for distinguishing between a prehominid and a euhominid group. Nevertheless the existence of *Telanthropus,* which is not a true australopithecine but has very distinct australopithecine affinities and also clear euhominid affinities, shows that the ancestral euhominid (even though this may not have been *Telanthropus* itself but a very closely related form) had characteristics of the sort found among the australopithecines. To say that this ancestor could not have been an australopithecine, as von Koenigswald does, is surely not being realistic. In the first place we certainly do not know all the types of australopithecine which existed. *Telanthropus* shows that there must have been a third line in this group which had some of the characters of the *Paranthropus* line and some of the *Australopithecus* line, but not all of either. In the second place it is difficult to see the objection to regarding "Meganthropus" as an australopithecine. The main characteristics of the australopithecine group are the relatively small brain coupled with erect posture and a predominantly euhominid-like dentition. The latter feature is the only one for which any direct evidence exists in the Javan specimen; therefore it is not possible to assert that it did not have the australopithecine group of characters. However, if "Meganthropus" is regarded as being an early euhominid ancestral to *Pithecanthropus* — which suggestion suffers from the immediate disadvantage that these two appear to have been synchronously present in Java — then presumably it did not have a larger brain than *Pithecanthropus.* The lower limit of brain size known for the latter is about the same as the upper limit known for the australopithecines, hence the brain of "Meganthropus" could hardly have been too large to fit into the australopithecine range. Then again, *Pithecanthropus* was fairly clearly erect walking. If "Meganthropus" was ancestral to it (or merely closely related) and lived at approximately the same time, it could hardly not have been erect walking too or very nearly so. Consequently it would have had the main australopithecine features and therefore merits that name. If it is considered that the suggested postural and brain-size characters were not present in the Javan form, hence that it is not australopithecine, the same fact would also have as a consequence very much reduced probability that it was closely related to *Pithecanthropus*.

The 'simian gap' in *Pithecanthropus* IV is regarded as important by von Koenigswald because it "is a very primitive characteristic which might be expected in an early human forerunner." This he regards as additional evidence that the australopithecines, as a group, could not be ancestral to euhominids as this feature is lacking in the former. However the maxillary diastema is not a simple feature and Schultz ('48) has shown that "Premaxillary diastemata are not necessarily related to large lower canines which require these gaps in the upper row of teeth" and "there is either no correlation, or else a tendency for an inverse relation, between the size of the maxillary diastema and that of the (upper) canines." The use of this diastema in predicting euhominid ancestors and their canine size is consequently a very unsafe procedure.

Maxillary diastemata are very common among pongids and, while they do occur occasionally and sporadically among euhominids, they are certainly not characteristic of the latter. For this reason one needs more evidence than its occurrence in the palate of Skull IV to show that this feature was characteristic of *Pithecanthropus*. But assuming that it was, as von Koenigswald does, then the fact that it is not characteristic of euhominids in general or of the known *Telanthropus* or australopithecine material — in fine that *Pithecanthropus* would then be the *only hominid* known of which it is characteristic — surely suggests caution. Under such circumstances the most logical conclusion, to my mind, would be that *Pithecanthropus* is well off the main stream of euhominid evolution and secondarily acquired some pongid-like features — as the classic Neanderthals did later. The absence of this diastema in the australopithecines and *Telanthropus* would then favour their being (as a group) in the line of descent rather than millitate against it.

On present evidence it would therefore seem the most logical course to regard the australopithecines from South Africa, as well as the East African and Javan forms, as being variations on a common theme. In South Africa two quite distinct forms exist. The East African form falls naturally into the one group, while the Javan form falls even more obviously into the other. There is insufficient evidence to determine with complete certitude the specific status of the latter two forms: the Laetolil specimen cannot adequately be separated from the Sterkfontein type but may well belong to a separate species, while the Javan form is fairly clearly specifically distinct from the South African species of *Paranthropus*. This arrangement not only agrees best with the available evidence, but renders more intelligible the evolutionary picture of the earlier hominids.

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SIMPLE MAXIMUM LIKELIHOOD METHODS FOR CALCULATING Rh GENE FREQUENCIES IN PACIFIC POPULATIONS[1]

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Examination of the tables in the book of Mourant ('54) reveals the fact that many Pacific populations exhibit a much simpler genetic structure, insofar as their Rh blood groups are concerned, than do European and Asiatic populations. Thus in populations like the natives of New Guinea, the Marshallese, the Gilbertese, the New Caledonians, the Admiralty Islanders, Fijians, and Cook Islanders (Fry, '55), only four or five Rh types are present, CDe/C (R_1R_1), CDe/c (R_1r), cDE (R_2), CDE/c (R_1R_2), and occasionally a little cDe (R_o). The composition of the population can be accounted for by assuming that only three genes, R_1, R_2, and R_o, are present. This circumstance makes the exact computation of the gene frequencies quite simple. If we let p represent the frequency of the R_1 gene, q the frequency of the R_2 gene, and r the frequency of the R_o gene, and designate, for later convenience, the different phenotypes by letters of the alphabet, we have the following relations, assuming genetic equilibrium:

PHENOTYPE	SHORT SYMBOL	EXPECTED FREQUENCY
CDe/C (R_1R_1)	H	p^2
CDe/c (R_1R_o)	K	$2pr$
CDE/c (R_1R_2)	P	$2pq$
cDe (R_o)	Q	r^2
cDE (R_2)	T	$q^2 + 2qr$

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The gene frequencies can be estimated from these expressions by the method of maximum likelihood. It will be remembered that this method proceeds by finding gene frequencies which make the following expression a maximum

$$L = H \log (p^2) + K \log (2pr) + P \log (2pq) + Q \log (r^2) + T \log (q^2 + 2qr)$$

where the letters H, K, etc. represent the numbers of persons observed to fall into the various classes, and p^2, $2pr$, etc. represent the expected frequencies of the various classes. This expression simplifies to

$$L = (2H + K + P) \log p + (P + T) \log q + (K + 2Q) \log r + T \log (q + 2r)$$

To find values of p, q, and r which make this expression a maximum, it is necessary to differentiate with respect to the variables, and find values of the variables which make the derivatives zero. Since $p + q + r = 1$, r is not independent of p and q, and we can substitute $r = 1 - p - q$ in the expression for L before differentiating. It is somewhat simpler, however, to proceed by the method of Stevens ('38) and note that $\partial/\partial p = \partial/\partial p - \partial/\partial r$ and $\partial/\partial q = \partial/\partial q - \partial/\partial r$, where in each of these equations the round d on the left of the equals-sign indicates differentiation with regard to p (or q) if $r = 1 - p - q$ is substituted into the expression for L, and the expressions to the right of the equals-sign show the way of computing these derivatives without preliminary substitution.

Performing the differentiations, we have

$$\partial L/\partial p = (2H + K + P)/p - (K + 2Q)/r - 2T/(q + 2r) = 0 \quad (1)$$

$$\partial L/\partial q = (P + T)/q - (K + 2Q)/r - T/(q + 2r) = 0 \quad (2)$$

As a rule it is not possible to solve such equations by straight-forward algebra, and it is necessary instead to insert trial values for the unknowns and calculate corrections by a method which is essentially Newton's method of approximations for finding the root of an equation (Boyd, '54c). In the present case, however, an explicit solution is possible. First convert the observed numbers in each class, H, K, etc., to frequencies $\overline{H}$, $\overline{K}$, etc. by dividing all equations by N, the total number examined. Then eliminate a term in r from the equations by subtracting (2) from (1). We obtain

$$(2\overline{H}+\overline{K}+\overline{P})/p-\overline{T}/(q+2r)-(\overline{P}+\overline{T})/q=0 \qquad (3)$$

Next we observe that the frequency p of the gene R_1 can be obtained exactly by gene counting, just as in the simpler MN case (Boyd, '54a), for none of the phenotypes containing R_1 are composite. Consequently we can write

$$p=(2\overline{H}+\overline{K}+\overline{P})/2 \qquad (4)$$

and since gene counting estimates are maximum likelihood (Wiener and Vaisberg, '31; Stevens, '38), this estimate is exact, and no further improvement is possible. This enables us to simplify (3) to

$$2-\overline{T}/(q+2r)-(\overline{P}+\overline{T})/q=0 \qquad (5)$$

Since $p+q+r=1$, we have $q+r=1-p$. Let $1-p=a$. Then we have

$$q+r=a \qquad (6)$$

Solving equations (5) and (6) for q and r, we have

$$q=\frac{(4a+\overline{P})-\sqrt{(4a+\overline{P})^2-16\,(\overline{P}+\overline{T})\,a}}{4} \qquad (7)$$

and

$$r=a-q \qquad (8)$$

where $\overline{P}$ and $\overline{T}$ indicate the observed frequencies, not the observed numbers.

Since these are exact solutions of the maximum likelihood equations, they require no further adjustment, and no process of successive approximations is involved. Since it is so simple to obtain the exact solutions for such populations, there seems no good reason to continue to use inexact or approximation methods in such cases. All that is necessary to obtain the best estimates is to substitute the observed frequencies into formulas (4), (7), and (8).

If desired, standard errors can be calculated for these estimates. First find the second partial derivatives of the likelihood function. We obtain

$$\frac{\partial^2 L}{\partial p^2} = -\frac{(2H + K + P)}{p^2} - \frac{(K + 2Q)}{r^2} - \frac{4T}{(q + 2r)^2}$$

$$\frac{\partial^2 L}{\partial q^2} = -\frac{(P + T)}{q^2} - \frac{(K + 2Q)}{r^2} - \frac{T}{(q + 2r)^2}$$

$$\frac{\partial^2 L}{\partial p \partial q} = \frac{\partial^2 L}{\partial q \partial p} = -\frac{(K + 2Q)}{r^2} - \frac{2T}{(q + 2r)^2}$$

Substitute the observed numbers in the various phenotype classes for H, K, etc., and the estimates obtained from the formulas for p, q and r. Let

$$Ipp = -\frac{\partial^2 L}{\partial p^2},\ Iqq = -\frac{\partial^2 L}{\partial q^2},\ Iqp = Iqp = -\frac{\partial^2 L}{\partial p \partial q} = -\frac{\partial^2 L}{\partial q \partial p}$$

Then the variances and covariance of the estimates are

$$V_p = I_q/(I_{pp}I_{qq} - I^2{}_{pq}),\ V_q = I_p/(I_{pp}I_{qq} - I^2{}_{pq}),\ V_{pq} = V_{qp} = -I_{pq}/(I_{pp}I_{qq} - I^2{}_{pq})$$

and the standard errors are

$$\sigma_p = \sqrt{V_p},\ \sigma_q = \sqrt{V_q},\ \sigma_r = \sqrt{V_p + V_q + V_{pq} + V_{qp}}.$$

If in addition to the genes R_1, R_2, and R_o, the gene R_z is also present, as in the Indonesians (Mourant p. 386), a new phenotype CDE/C (R_1R_z) is present, which we may designate as J for short. If we represent the frequency of the R_z gene as s, we now have the following expected frequencies:

SHORT SYMBOL	PHENOTYPE	EXPECTED FREQUENCY
H	CDe/C	p^2
J	CDE/C	$s^2 + 2ps$
K	CDe/c	$2pr$
P	CDE/c	$2pq + 2qs + 2rs$
Q	cDe	r^2
T	cDE	$q^2 + 2qr$

The above formulas for the gene frequencies do not work with such populations, and to obtain the maximum likelihood estimates of the gene frequencies it is necessary to start with trial values and calculate corrections to these. A method of doing this, based on Fisher's method of free parameters, has been published by Williams ('49). However, in this method, although it is somewhat simplified, it is still necessary to construct 4 × 4 matrices and invert 3 × 3 matrices. The calculations can be done much more simply, without formally constructing a matrix at all, by the method published (Boyd, '53, '54b) for MNS data, for it will be noted that the six Rh classes H, J, etc. form a set of six phenotypes with genetic formulas exactly like the six MNS classes. It is only necessary to make use of the following correspondences:

$H = M$
$J = MS$
$K = MN$
$P = MNS$
$Q = N$
$T = NS$

$p = m_s$
$s = m_S$
$r = n_s$
$q = n_S$

Starting with trial values for p, q, r, and s [which can be obtained by Mourant's methods for MNS (Mourant, '54; Boyd, '54b)], and substituting into the equations in my paper the observed numbers in the appropriate Rh classes according to the above scheme, corrections giving the maximum likelihood estimates of the gene frequencies are easily obtained. Standard errors for the estimates can be calculated not from the (incorrect) formulas in my MNS paper (Boyd, '54b), but from the new formulas in my letter to the editor (Boyd, '55).

Illustrative calculations

Simmons et al. ('53) found for 159 Gilbertese the following frequencies (see Mourant, p. 386):

CDe/C	0.4780
CDe/c	0.1069
CDE/c	0.3270
cDe	0
cDE	0.0881

Applying the formulas for the frequencies of R_1, R_2, and R_0 when R_z is absent, we obtain $p = 0.6950$, $q = 0.2352$, $r = 0.0698$ which are the same as the frequencies given by Mourant.

The standard errors of these estimates turn out to be $\sigma_p = 0.0258$, $\sigma_q = 0.0246$, $\sigma_r = 0.0156$. For the 112 Admiralty Islanders studied by Simmons and Graydon (Mourant, p. 385) we obtain $p = 0.9330$, $q = 0.0374$ and $r = 0.0296$. Mourant gives 0.9330, 0.0364 and 0.0306. Calculating $\chi^2_{(1)}$ from the observed frequencies and the expected frequencies based on the two sets of gene frequencies, we obtain $\chi^2_{(1)} = 0.579$ for the set derived by the above method and 0.590 for Mourant's set. The fit to the data has been improved, although very slightly. However, since the method proposed here is fully as easy as any alternative, and always gives the maximum likelihood estimates, it would seem to be the method of choice.

For 100 Indonesians Simmons and Graydon (see Mourant, p. 386) found the following Rh types:

CDe/C	64
CDE/C	3
CDe/c	9
CDE/c	20
cDe	1
cDE	3

Application of my MNS method to these data gives the frequencies $p = 0.7964$, $s = 0.0186$, $r = 0.0639$, $q = 0.1211$. Mourant gives 0.7849, 0.0301, 0.0753 and 0.1097. From the expected frequencies calculated from these two sets of gene frequencies it is found that $\chi^2_{(2)}$ for Mourant's set is 1.946 and for the set calculated by the maximum likelihood method 0.999. It is apparent that a definitely improved fit to the data has resulted from the application of the relatively simple MNS method to these Rh data.

SUMMARY

It is shown that in populations, such as many in the Pacific, whose Rh blood groups can be accounted for on the assumption that only three genes are present, R_1 (CDe), R_2 (cDE), and R_o (cDe), the maximum likelihood estimates of the gene frequencies can be obtained by explicit formulas which involve no successive approximations and need no further ad-

justment. When the gene R_z (CDE) is also present these simple formulas do not work, but it is shown that in such cases a simple maximum likelihood method previously published for the MNS system can be used. Illustrative calculations are given.

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PHYSICAL ANTHROPOLOGY AND THE FREQUENCY OF GENES WITH A SELECTIVE VALUE: THE SICKLE CELL GENE

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ONE FIGURE

The great value of gene frequencies in physical anthropology is now widely accepted. Boyd ('50) has pointed out some of their advantages over the anthropometric method. According to him, the best characteristics for the study of racial differences are normal physiological characters inherited by a known genetic mechanism, not too infrequent nor too frequent, showing stable frequencies in populations and considerable variation between populations (the blood groups being the best known example).

Since the interests of anthropologists include not only pure taxonomy, but also the racial history of man, they naturally try to establish a classification of living man that is meaningful for his phylogenetic tree. This implies the use of relatively non-adaptive characters. If a genetically determined character has a high adaptive value for a given environment, it is likely that it will reach a high frequency anywhere it encounters that environment, provided the determining genes exist in the different stocks. (This could be the case with the distribution of dark skin.) Basing a classification of living populations on such adaptive characters might lead to putting in the same class, populations derived from quite different stocks.

These considerations do not imply that the study of adaptive characters is of no interest to physical anthropology (such study provides in fact many data of great value for the problems of human evolution); they only point to the dangers of the use of adaptive characters in a phylogeny-minded classification. They will here be illustrated by the case of the sickle cell phenomenon, a feature often mentioned in recent anthropological papers.

Sicklemia, an abnormality of the blood, is characterised by a special sickle-like shape of the erythrocytes in preparations of oxygen-deprived blood: this is sometimes also visible in the usual stained blood-smears. The majority of the bearers of this abnormality do not seem to suffer from it, but a small proportion exhibit a severe disease called sickle-cell anemia, and usually die before reaching the reproductive age.

Neel ('49 and '51) elucidated the genetic mechanism of the phenomenon: sicklemia is transmitted by a monohybrid diallelic mechanism, involving a sicklemic gene S and a normal allele s. The sicklemic homozygotes (SS) suffer from sickle cell anemia; the heterozygotes (Ss) bear only the sickle cell trait; the normal homozygotes (ss) do not exhibit the phenomenon.

As sickle cell anemia is usually lethal in the young, there is, in each generation, an important loss of S genes: if F is the frequency of the sicklemics in an adult population, all of them being supposed heterozygotes, the frequency of the gene S is $f = F/2$; the frequency of homozygotes SS in the next generation will be $F^2/_4$; if all of them die the gene loss will be $2 \times F^2/_4 = F^2/_2$ or $2f^2$.

It is now known that even in the heterozygous state the S gene may be eliminated by fatal disease: the combination of an S gene with one responsible for thalassaemia (Silvestroni and Bianco, '52) or with one determining hemoglobin C (Kaplan, Zuelzer and Neel, '51) may result in a disease similar to sickle cell anemia.

We do not know exactly how many S homozygotes live to become adults, but we may safely state that the gene loss is important in each generation.

If there were no compensatory mechanism for this loss, the gene frequency should fall off quickly, in a hyperbolic way. This would imply that the populations now showing sicklemia should have had a much higher gene frequency a few generations ago (several populations now have about 40% of sicklemics). This is hardly credible, and would make more difficult the problem already posed by the existing frequencies: how have such high frequencies arisen, when the gene is so unfavorable in its homozygous state?

The sicklemic gene seems to be entirely lacking in a large part of the world: in the europoid populations except near the shores of the Mediterranean, in Asia except small groups of Indian Veddoids, in America where there has been no mixture with Negroes, and in Australia. With a few (but important) exceptions, the gene is confined to the Negro race. The gene thus seems to have arisen by mutation relatively late in human evolution, and not to have succeeded in spreading through the whole of mankind, although it has reached a high frequency in a large area of Africa.

Several hereditary defects are known in man, whose gene frequencies result from the balance between gene production by mutation and gene elimination by lethal effects. These are rare diseases, and the mutation rate necessary for their maintenance is of an order of magnitude of 10^{-5} (see Neel, '52).

If the high frequency of sicklemia in Africa were to be explained merely on the basis of a high rate of mutation, this would have to be of the order of 10^{-2} in many populations (Neel, '51), or about a thousand times previously known rates.

But in that case we should be confronted with a geographic distribution of a mutation rate nearly identical to the geographic distribution of the gene frequency, and we should have to ask the further question: what are the factors determining this mutation rate? Are they environmental? If so, in the long run the gene frequency would be environmentally determined. Or are they hereditary? If so, we fall into a vicious circle, for we have to explain the distribution of the gene supposed to control the mutation rate.

It thus seems that even when trying to explain the frequency of sicklemia by mutation we cannot escape postulating an environmental influence.

A more direct action of such an influence may be proposed as an alternative solution to the high mutation rate, i.e. a selective advantage of the heterozygote over the normal homozygote. If there is such an advantage, a state of balance will be reached between the gene gain thus resulting and the gene loss due to lethality of the SS combination (the proportion of SS homozygotes increases when the S gene frequency rises).

Data are now accumulating on the population genetics of sicklemia. No definitive conclusion has been reached yet, but certain data seem to indicate a relation between the sickle cell trait and malaria: the sicklemics seem to be more or less immune to malaria (Allison, '54). This would give a strong positive selective value to the sickle cell gene in a large part of the world (a survey of the United Nations indicated an approximate number of 693,000,000 persons affected by malaria in 1933). It is true that sicklemia is absent in many areas where malaria is severe, but of course a gene frequency cannot increase by selection where the gene does not exist.

My own data on a small group of villages in Urundi show a lower infantile mortality amongst the children born from sicklemic × normal matings, thus indicating a selective advantage of the heterozygotes; but they do not exclude the possibility of a high mutation rate.

Other personal data show a statistically significant difference in body weight in an adult group in favor of the sicklemics over the normal individuals, also pointing to some biological advantage of the heterozygotes (Hiernaux, '52 and '55).

Whatever the exact compensatory mechanism involved in the S gene frequency balance, the important points for the use of sicklemia in human systematics are:

(1) The sicklemic gene is absent in a large part of the world.

(2) Where present, its frequency is the result of an equilibrium between a favorable mode of action and an unfavorable one.

The first fact gives to sicklemia a discriminating power of great value for systematics when its "presence or absence" is used. The second fact, on the other hand, shows that the use of its frequency for the classification and phylogeny of the populations where it exists is dangerous: a migratory group can diverge sharply from the parent population in respect to the S gene frequency in a few generations, if the ecological factors acting are different in the new environment. A sudden change in the ecological factors in one region will induce a quick shift in the gene frequency, the other gene frequencies remaining more or less stable (such sudden environmental change has occurred frequently in the case of malaria, whose spread and intensity varied greatly during historical time).

If such a phenomenon occurs, the sicklemia gene frequency will vary much more among related populations than the frequencies of less adaptive genes. Data on this question were collected by me.[1] In an area inclosing Ruanda-Urundi and an adjacent part of Belgian Congo, every tribe was tested for blood-groups of the ABO and MN systems and for sicklemia (in that region, tribe or ethnic group is more or less synonymous with panmictic population, while the tribal frontiers act as relative genetical barriers). The data are here restricted to the "Bantu" agricultural tribes: the Ethiopid Tutsi and the pygmoid Twa are not considered, since they evidently belong to different racial groups. The samples, all adult individuals, are of 300 for the Shu, Swaga, Nianga, Hunde; for the Mbuba they are of 334 (sicklemia) and 300 (blood groups); for the Hutu, 798 (sicklemia) and 267 (blood groups); for the Shi, 375 (sicklemia) and 200 (blood groups).

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[1] Part of the following data are given in Hiernaux ('55).

TABLE 1

Gene frequencies of adjacent tribes and their ratios

TRIBE	FREQUENCY	TRIBE	FREQUENCY	RATIO
Mbuba	$p = 154$	Shu	$p = .211$	1.37
	$q = .122$		$q = .099$	1.23
	$m = .525$		$m = .451$	1.16
	$S = .172$		$S = .045$	3.82
Shu	$p = .211$	Swaga	$p = .224$	1.06
	$q = .099$		$q = .108$	1.09
	$m = .451$		$m = .483$	1.07
	$S = .045$		$S = .038$	1.18
Swaga	$p = .224$	Nianga	$p = .194$	1.26
	$q = .108$		$q = .111$	1.03
	$m = .483$		$m = .465$	1.04
	$S = .038$		$S = .036$	1.05
Nianga	$p = .194$	Hunde	$p = .222$	1.14
	$q = .111$		$q = .110$	1.01
	$m = .465$		$m = .485$	1.04
	$S = .036$		$S = .021$	1.69
Hunde	$p = .222$	Hutu	$p = .166$	1.33
	$q = .110$		$q = .128$	1.16
	$m = .485$		$m = .513$	1.05
	$S = .021$		$S = .042$	2.00
Hutu	$p = .166$	Shi	$p = .198$	1.19
	$q = .128$		$q = .131$	1.02
	$m = .513$		$m = .510$	1.00
	$S = .042$		$S = .021$	2.00

Table 1 gives a comparison of gene frequencies between 6 pairs of contiguous populations. The genes considered are p (I^A), q (I^B), m (L^M) and S (sicklemia).[2] The last column gives, for each gene, the ratio of the higher frequency to the other, thus a function of the relative difference between gene frequencies in the two populations.

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[2] p and q are calculated from Bernstein's formulas with Bernstein's adjustments; m by gene counting and S is half the frequency of adult sicklers. p, q and m have been subjected to the χ^2 tests with expected frequencies and in all cases are statistically satisfactory.

In 5 comparisons over 6, the ratio is by far the highest for the sicklemic gene. If we pool the 6 comparisons, the mean ratios are:

for p : 1.22	for m : 1.06
for q : 1.09	for S : 1.95

The mean ratio for the S gene is close to 2: as an average, the gene frequency doubles when passing a tribal border, while the frequencies of p, q and m show a variation of only 22%, 9% and 6% of the lower frequency. (Incidentally, the data also show a greater variability of p over q and m.) The instability of the sicklemic gene frequency, already suspected upon theoretical grounds, is here demonstrated. Genetic drift is highly unlikely to have occurred, since the size of the populations is large and it is seen that genetic drift did not occur for p, q and m (though these gene frequencies are more sensitive to drift, for the drift pressure on them is much less opposed by selective pressure).

Let us now examine the world distribution of sicklemia and see what we can — and what we cannot — deduce from it, in the light of the preceding considerations.

1. *Presence or absence of the gene*

The gene is known to be present in a large part of Negro Africa, in Europe near the shore of the Mediterranean (Italy and Greece), in Arabia, in a few Southern Indian tribes, in America wherever Negroes live and in a few Amerindian tribes known to have Negro blood. This is surely one of the most systematic distributions of a human gene. It shows a big and compact main area (Negro Africa) with spreading into areas where Negroes are known to have migrated (America), patches in regions adjacent to Africa (Southern Europe and Arabia, where contact with Negroes is also historically known), and a more remote little patch in India. In Africa itself, the gene is absent among the Bushmen. The association between the presence of the sickle cell gene and the presence of Negro blood appears to be nearly absolute, and the apparent exceptions have to be critically examined.

(I agree on this point with the views of Singer, '53.) The instability of the gene frequency has to be remembered here. A patch of high frequency outside Africa does not imply an important gene spread: the selective value of the gene — and genetic drift in small communities — is sufficient to raise an initially low frequency considerably. This is surely the case for Greece, where a little area around Petromagoula exhibits a high frequency, while a sample from other parts of Greece showed no sickler. Only minute African influence would be suspected from other gene frequencies; for instance a small rise of R_0 over the general European frequency (Choremis et al., '53).

The sickle cell gene thus appears as a tracer of the intrusion of Negro blood, but it is not possible to measure this intrusion quantitatively by the frequency of the sickle cell gene. We can also state that the gene appeared in human evolution after the separation of the Bushmen's ancestors from the stock who gave rise to the Negroes. I shall discuss the Veddoid theory of Lehmann later.

2. *Comparison of observed frequencies*

As we have seen, nothing may be safely concluded from the existing frequencies as to the phylogenetic relationship of the populations exhibiting the sickling phenomenon, owing to the instability of the gene frequency. In particular, we cannot safely deduce either the center of diffusion of sicklemia or the racial group or groups in which this feature arose. One thing only may be said: sicklemia is very unlikely to have arisen in racial groups which today systematically show a lower frequency than the surrounding groups. Two such groups are known in Negro Africa:

(a) The Ethiopids, also called "Hamites." Lehmann and Raper ('49) were the first to show, from Uganda, that their frequency of sicklemia is very low, generally much lower than among the Nilotic and Bantu tribes. I recorded the same situation in Ruanda-Urundi, where the ethiopid Tuts show 1% of sicklers while living among the Bantu Hutu who have 8% (Hiernaux, '52). The few Tutsi cases may even logically be explained by the intrusion of Hutu blood among the Tutsi, a fact observed in the country at the present time. An anthropometric analysis showed the affinities between Tutsi and Somali; there was no sickler among 50 of these later Hamites tested by Lehmann ('54).

Quite different is the picture from French West Africa, where the ethiopid Peuls show a higher frequency of sickling (11%) than the Negro Ouolof, Lebou and Bambara (6%) (Pales and Linhard, '52). But this group of Peuls is largely negriticized, and the instability of sickle cell gene frequency may explain the case: this shows again that no confidence may be put on this frequency for the quantitative study of the components of an ethnic group. Moreover, we do not know with which populations, nor with what sickling frequencies the Peuls have been in contact in the past. This exception, therefore, does not invalidate the general picture of low frequency among the Ethiopids.

TABLE 2

Frequency of sickle-cell trait among Pygmoids and adjacent Negro populations

AUTHOR	PYGMIES OR PYGMOIDS	% SICKLERS	ADJACENT NEGROES	% SICKLERS
Hiernaux, '52	141 Twa of R-U	2.8	798 Hutu of R-U	8.5
Hiernaux, '55	295 Twa Kuba	18.9	388 Bushong	21.3
Hiernaux, '55	104 Bolia's Twa	13.4	213 Bolia	16.4
Ravisse, '52	327 Babinga	6.8	221 Bondjo	25.3
van den Berghe and Janssen, '50	456 Efe Pygmies	25.9	217 Mamvu	22.1

(b) The pygmies and pygmoids. They generally show a lower frequency of sicklemia than the surrounding populations, as shown in table 2. In all cases but one, the frequency is lower in the Pygmoids. The most striking difference is between the Bondjo and the Babinga, who are true Pygmies. The difference is also high in Ruanda-Urundi between the Bantu

Hutu and the pygmoid Twa. It is low between Negroes and Pygmoids of the Kuba and Bolia tribes, who have been in contact for a long time. The data of van den Berghe and Janssen ('50) show a reverse situation: a slightly higher frequency among the Efe Pygmies than among their Bantu neighbors. This only exception is again what is expected to occur frequently in the light of the instability of the gene frequency. On the whole, the Pygmies and Pygmoids have fewer sicklers than other Negroes; there is no reason for regarding them as the group where sicklemia originated; but no reason either for certainly rejecting them.

However, Singer ('53) states that "the focal center of the sickle cell in Africa appears to be in the Pygmy Negritoes in the region of the Ruwenzori Mountains." He reaches this conclusion on the basis of the following points:

1. The center of origin of the trait is probably where the frequency is now the highest (this is an unsafe assumption, as we have seen).

2. The highest recorded frequency is among the Amba, who live at the foot of the Ruwenzori Mountain (Lehmann and Raper, '49, recorded 45% of sicklers among 140 Amba).

3. The Amba are saide by Lehmann and Raper to be Pygmoids. But the later authors give no anthropological justification of such an affirmation. Coming again to this question, Lehmann ('54) states that the Amba are a pygmoid tribe, and in the same paragraph, that, of all the tribes he investigated with Raper, they are the nearest to the "arch type" of the Negro. This makes a difference. Forest Negroes and Pygmoids, though mixing at a slow rate where they live close to each other, still keep their individuality (see Gusinde, '48).

I have made an anthropological survey of the Humu tribe of the Belgian Congo. The Humu live on the Uganda border of Congo. They claim to be one and the same tribe with the Amba, who inhabit, close to the Humu, the Bwamba plain, artificially divided by the border. It is to be noted that the Humu are far from living as do their neighbors, the Pygmies of the Ituri forest: their huts and villages are quite different, they are sedentary agricultural people, though hunting plays an important part in the men's activities (which is quite logical in a region abounding in big game).

All the available Humu adults were tested for sicklemia. Ninety-nine sicklers were detected in 273 individuals, thus giving a frequency of 36%, which is extremely high, though lower than the frequency of 45% found by Lehmann and Raper on a sample of 140 Amba (the difference is not significant: $\chi^2 = .68$).

One hundred male adults were measured. Table 3 gives the mean of 4 characteristics especially sensitive in Africa to racial differences and inclusion of Pygmy blood. My 100 Humu and the 510 true Pygmies in the Ituri forest, measured by Gusinde ('48) are compared. (The samples of Pygmies of Gusinde and that of van den Berghe and Janssen giving 25% of sicklers are taken from the same area.) The Humu appear far less "pygmoid" than the Ituri pygmies: they are just forest negroes, with possibly a certain amount of pygmy blood.

TABLE 3

Means of 4 metric characteristics for 100 Humu and 510 Bambuti Pygmies

	HUMU	BAMBUTI PYGMIES
Stature (cm)	157.8	144.0
Nasal index	94.4	103.7
Facial index	81.4	78.3
Mouth height (mm)	24.2	15.4

The ABO blood groups confirm this belief. On the following Streng's schema are plotted the position of 248 Humu tested by me, 113 Amba tested by Allison, Ikin, Mourant and Raper ('52), and 1032 Bambuti Pygmies tested by Jadin ('35) in the same area as the metric sample of Gusinde and the sicklemia's sample of van den Berghe and Janssen. Also shown is the position of a sample from a Bantu population noticeably hamitized, the 267 Hutu of Ruanda-Urundi tested by Hubinont, Hiernaux and Massart Guiot ('53) (they are more or less the group named "Banyaruanda" and "Barundi" in Lehmann and Raper ('49), though the later names cover three entirely distinct ethnic groups, the ethiopid Tutsi, the bantu Hutu and the pygmoid Twa). Also given is the position of a sample of 100 Babinga Pygmies tested by Miletto ('51). The gene frequencies used in the schema are given below (table 4). If they were not calculated by Bernstein's formulas and adjustments in the original papers, I recalculated them that way. The test D/σ shows that all observed group frequencies fit with the theoretical distribution.

TABLE 4

Gene frequencies of the ABO systems in 5 samples

ETHNIC GROUP	SAMPLE	p	q	r	D/σ
Humu	248	.1668	.0950	.7381	.89
Amba	113	.1807	.1282	.6910	.78
Bambuti Pygmies	1032	.2275	.2193	.5532	.05
Babinga Pygmies	100	.2393	.2262	.5345	.32
Hutu	267	.1663	.1288	.7047	1.57

The samples of Humu, Amba and Hutu do not differ significantly, neither do the samples of Bambuti and Babinga Pygmies; both groups of samples are widely separated. This greatly strengthens the results of the anthropometric analysis: the Humu-Amba are far from the Pygmies, even if they have some pygmy blood acquired by mixture. But the Bambuti and Babinga, true pygmies, show respectively 25 and 6% of sicklemia, while the samples of Amba and Humu show 45 and 36%! It is quite illogical to regard the Pygmy groups as the ethnic center of diffusion of sicklemia. Singer's hypothesis, based on the statement of the pygmoid status of the Amba by Lehmann and Raper, thus appears to lack any support from the data. This shows how misleading the use of racial terms can be when they are not justified by anthropological analysis.

At the present stage of our analysis of the distribution of the sicklemic gene, the following statements seem safe: sicklemia appeared somewhere in the ethnic stock, or in one of the ethnic stocks, involved in the living Negro, after the forking of the Bushmen and Ethiopid branches, and probably not in the Pygmy or African Negrito race, thus also probably after these groups had diverged from the main Negro stem. The frequency of the gene rose to very high values in a few groups, owing to its selective value and possibly to genetic drift. The center of origin or the ethnic group in which it originated cannot be safely determined from the present distribution. Neither may sicklemia be safely used for a

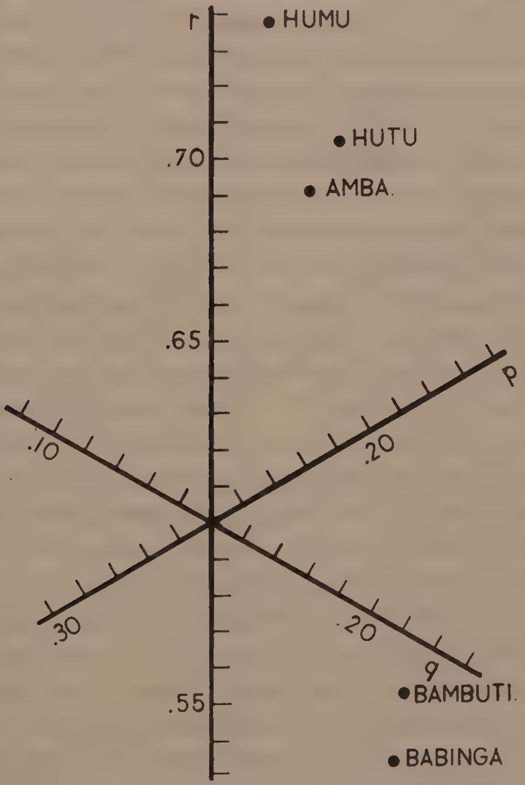

Fig. 1 Position of 5 samples on a Streng's schema.

quantitative analysis of the components of a population. This later point is exemplified by the flagrant case of Greece. However, Lehmann and Raper ('49) and Lehmann ('54) claimed to find a systematic cline of sickling frequency. Lehmann says: "The higher the sickling rate the lower will be the admixture of physical Hamitic features in any one Bantu tribe (of Uganda)." For proving this, he contrasts the low frequency among Uganda's Bantu Tribes, and states that the more important and long-continued has been the contact with Hamites, the more "hamiticized" is the physical type and the lower the sickling rate. On the other hand, he states, the sickling rate is highest, the farther away the Bantu tribe lives from the invasion route of the Hamites. But no data, metrical or serological, are given to show the degree of hamitization of the given tribes, and facts disagreeing with the cline are ignored. For example: (1) The so-called "pygmoid" Baamba, with 45% of sicklers, are considered as displaying the physical type most remote from the Hamites. Lehmann ('54) does not consider the Twa, those pygmoid hunters living near the junction of Uganda, Congo and Ruanda borders, who display a sickling rate of only 2.8% (Hierneaux, '52) although their physical type is clearly more remote from the Hamitic (stature 152.9 cm, nasal index 95.8, facial index 81.0, mouth height 19.0 in Gusinde, '49). (2) The Banyaruanda are opposed to the Barundi in regard to the contact with Hamites, the former being said to show in their traditions and customs a very prolonged contact with the Hamites, and to have an aristocracy possessing hamitic features. In reality, the Barundi have been shown in many ethnological papers to possess the same Hamitic aristocracy as the Banyaruanda, i.e. the Tutsi, forming in both Ruanda and Urundi about one-tenth of the population ("Banyaruanda" and "Barundi" only mean inhabitants of Ruanda and Urundi). The degree of hamitization is about the same in both countries (Hiernaux, '54). The large difference in sickling rate must be explained on another basis than on different amounts of hamitic influence. (3) I have shown that the Shi tribe of

Belgian Congo is closely akin to the Hutu of Ruanda (the Banyaruanda of Lehmann), the only difference being a lesser hamitization of the Shi; however, their sickling frequency is one-half that of Ruanda's Hutu (Hiernaux, '53). It thus seems contrary to the facts to assert a strict parallelism between sickling rate and hamitization rate, even in Uganda.

It is evident that mixture between two groups, the one having a high and the other a low sickling rate, will result in a group showing an intermediate frequency in the first generation. But it is quite unsafe to postulate that such resulting frequencies will remain unchanged. The three points developed above show once more that we have to take in account the unstability of sicklemic gene frequency.

This instability allows us, theoretically, to imagine the center of origin of the gene to have been anywhere we now find it present. Singer ('53) locates it in the region of the Ruwenzori Mountains, where a small patch of very high frequencies is surrounded by much lower ones. This is merely one possibility. Reasoning as Singer does one would be equally tempted to locate the center of origin in Portuguese East Africa, where Foy, Kondi, Rebello and Martins ('52) found a patch of frequencies equally high (39% among the Makonda-Makua against 39% for the pooled Amba-Humu samples) surrounded by low frequencies. It would be interesting to compare both groups by the means of metrical and serological features; the lack of data on the Makonda and Makua hinders such a study, and for the moment we cannot go further than to note the fact of two small centers of very high frequencies.

The most elaborate theory so far published on the center of origin of the sickle cell gene is that of Lehmann ('54); he locates it in the Veddoids of India (i.e. in a few small ethnic groups) who show a high incidence of sickle cell trait (31% in a sample of 201 persons) while no R_0 gene was found among 156 of them (Lehmann and Cutbush, '52). Their physical appearance recalls the "arch type of the forest negro." They are surrounded by populations lacking the sickle cell gene and displaying Mediterranean features. A connection thus would exist between the Veddoids and Africans; the absence of R_0 in the former excludes a gene spread from Africa (R_0 shows a high incidence in all ethnic groups of Black Africa, including the Bushmen) to the Veddoids. The migration of Veddoid elements to Africa is thought to be the most satisfactory explanation of the present situation: they brought the sickle cell gene, and somewhat lowered the African R_0 frequency. A link between India and Africa may be found in Arabia, where a tribe, the Zabidi, shows 23% of sicklers and 28% of group R_0, while their physical appearance shows a Veddoid or African influence.

However this interpretation, though impressive, is only one of the possible ways of explaining the existing distribution. We know that a minute introduction of sicklemia into Greece resulted in a patch of high frequency, without any other visible Negro of Veddoid influence except a small rise in R_0 frequency, in a large Mediterranean area; a similar minute introduction of Negro blood bringing sicklemia among the Indian Veddoids may logically be invoked; genetic drift is active in such small communities and can suppress the R_0 gene or lower its frequency so that it does not appear in a sample of 156 persons; the physical similarities between Veddoids and Negroes are as favorable to one thesis as to the other. The Arabian link also fits perfectly to the thesis opposite to Lehmann's: the sickle cell gene and R_0 frequencies of the Zabidi are what we can expect from a pronounced Negro influence: the 28% of R_0 cannot be explained on any other basis. Moreover, no sickle cell trait has been found in a sample of 72 Australian aboriginals from a region where an important Veddoid component is supposed (Horsfall and Lehmann, '53) while the Veddoids of India have a frequency of R_z that in fact indicates a link with Australia (Lehmann and Cutbush, '52).

SUMMARY

It is concluded that physical anthropologists should be very cautious when working with a highly adaptive character, and should keep constantly in mind the implications of its value in natural selection. Such prudence is certainly needed when trying to interpret the distribution of sickle cell trait. The published hypotheses as to the origin and spread of the sickle cell gene must be examined in the light of all possible factors affecting the gene frequencies. It seems that from the available gentical data it is not possible to prove, or to disprove, Lehmann's Veddoid theory, which is no more probable than the reverse hypothesis.

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THE INHERITANCE OF THE BLOOD GROUP AND SECRETOR GENES IN THE BLOOD INDIANS OF ALBERTA, CANADA[1]

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THREE FIGURES

In a previous paper, (Chown and Lewis, '53), we reported the distribution of the genes for 9 blood group systems and the secretor system in the Blood and Blackfoot Indians of Alberta. The present paper is an analysis of the inheritance of these genes in the Blood Indians, the analysis being based on the above data and on additional families which were selected in an attempt to identify the *Rh* chromosomes *cDe, cde, Cde, cdE, CDE* and *CdE*. The latter families were excluded from the original paper.

In those systems in which the genotype could be determined by sera defining two antithetic genes, i.e., in the *M-N* system by anti-*M* and anti-*N*; in the *Rh* gena systems *C-c,* by anti-*C* and anti-*c,* and *E-e,* by anti-*E* and anti-*e,* the expected number of children of each genotype from each class of mating was determined by simple inspection. In those systems in which only the phenotype could be determined, i.e., in the *A-B-O, S-s, Kidd* and *Duffy* systems, the expected number of children from each class of mating was based on the previously calculated gene frequencies. In those systems in which

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the population, both adult and child, was homozygous for a particular gene, i.e., in the *Lutheran, Kell, Lewis* and *Secretor* systems, no calculation was necessary. The results are set out in tables 1 to 6.

The *Lutheran, Kell* and *Lewis* blood group systems and the *Secretor* status

Due to a shortage of anti-Lu^a serum only 20 matings were tested for the *Lutheran* antigen; all were $Lu(\text{a}-) \times Lu(\text{a}-)$. In 35 $K- \times K-$ matings 129 of the children were tested for the *Kell* antigen and all were $K-$. In 35 $Le(\text{a}-) \times Le(\text{a}-)$ matings 132 children were tested for the Le^a antigen and all were $Le(\text{a}-)$. In 30 *Sec.* × *Sec.* matings 115 children were tested and all but one found to be *Sec.* This child reacted as $Le(\text{a}-)$.

The distribution of the blood group genes in the offspring of observed matings

TABLE 1

The *A-B-O* System

OBSERVED MATINGS		NO. OF CHILDREN	O		A_1		B		A_1B		χ^2
No.	Class		Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	
13	$O \times A_1$	45	13.12	13	31.88	32					.00
19	$A_1 \times A_1$	80	6.80	5	73.20	75					.52
1	$A_1 \times B$	2	0.29	0	0.70	0	0.30	0	0.71	2	
2	$A_1 \times A_1B$	8			4.00	3	1.17	4	2.83	1	

TABLE 2

The *M-N* System

OBSERVED MATINGS		NO. OF CHILDREN	MM		MN		NN		χ^2
No.	Class		Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	
13	$MM \times MM$	52	52.00	52					
19	$MM \times MN$	72	36.00	42	36.00	30			2.00
3	$MN \times MN$	11	2.75	2	5.50	8	2.75	1	

TABLE 3

The *S-s* System

OBSERVED MATINGS		NUMBER OF CHILDREN	*S*+		*S*–		χ^2
No.	Class		Exp.	Obs.	Exp.	Obs.	
17	*S*+ × *S*+	74	63.20	64	10.80	10	.07
15	*S*+ × *S*—	51	31.52	22	19.48	29	7.53
3	*S*— × *S*—	10			10.00	10	

TABLE 4a

The *Rh* System (*C-c*)

OBSERVED MATINGS		NUMBER OF CHILDREN	*CC*		*Cc*		*cc*		χ^2
No.	Class		Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	
2	*CC* × *CC*	6	6.00	6					
11	*CC* × *Cc*	41	20.50	21	20.50	20			.02
12	*Cc* × *Cc*	34	8.50	8	17.00	19	8.50	7	.52
4	*CC* × *cc*	16			16.00	16			
5	*Cc* × *cc*	30			15.00	18	15.00	12	1.20
1	*cc* × *cc*	8					8.00	8	

TABLE 4b

The *Rh* System (*E-e*)

OBSERVED MATINGS		NUMBER OF CHILDREN	*EE*		*Ee*		*ee*		χ^2
No.	Class		Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	
5	*EE* × *Ee*	26	13.00	12	13.00	14			.16
13	*Ee* × *Ee*	43	10.75	8	21.50	25	10.75	10	1.32
1	*EE* × *ee*	3			3.00	3			
13	*Ee* × *ee*	50			25.00	26	25.00	24	.08
3	*ee* × *ee*	13					13.00	13	

TABLE 5

The *Duffy* System

OBSERVED MATINGS		NUMBER OF CHILDREN	*Fy*(a+)		*Fy*(a–)		χ^2
No.	Class		Exp.	Obs.	Exp.	Obs.	
30	*Fy*(a+) × *Fy*(a+)	102	97.85	100	4.15	2	1.16
5	*Fy*(a+) × *Fy*(a—)	24	19.16	20	4.84	4	.19

TABLE 6

The *Kidd* System

OBSERVED MATINGS		NUMBER OF CHILDREN	*Jk*(a+)		*Jk*(a–)		χ^2
No.	Class		Exp.	Obs.	Exp.	Obs.	
30	*Jk*(a+) × *Jk*(a+)	78	74.31	75	3.69	3	.04
4	*Jk*(a+) × *Jk*(a—)	15	11.74	12	3.26	3	.03

It will be seen that the agreement between expected and observed is good in all cases except the S-s system. We have therefore studied the data concerning this last group in some detail. The discrepancy between the expected and observed lies essentially in the matings $S+ \times S-$, there being too few $S+$ children and too many $S-$. The $S+ \times S-$ matings consist of $SS \times ss$ and $Ss \times ss$. The children are derived from 15 such matings. Inspection of the family records reveals that, of these, the $S+$ parent is Ss in 14 and SS in only one. The expected distribution of SS : Ss in $S+ \times S-$ matings in this population is 11 : 36, so that in the $S+ \times S-$ sample there is a shortage of SS parents and consequently of $S+$ children. If the children of the one $SS \times ss$ mating are eliminated the resulting calculation of $Ss \times ss$ is:

NUMBER OF CHILDREN	$S+$		$S-$		χ^2
	Exp.	Obs.	Exp.	Obs.	
45	22.5	16	22.5	29	3.76

It seems probable therefore that the divergence from expectation in the S-s system matings is dependent upon a chance sampling error.

These data were examined in other ways. The inheritance of the linked genes MS, Ms, NS and Ns was examined and in no case was there an exception to the accepted conception of their inheritance. This could be followed in most cases through three generations. Only one $S-$ child was as young as one year of age, so that the late development of the antigen did not appear to be a tenable explanation, nor do the published data of others suggest that the S-s antigens are not present at birth. Finally a comparison was made between the matings ♂ $S \times$ ♀ s and ♂ $s \times$ ♀ S: the former produced 17 $S+$ and 18 $S-$ children; the latter 5 $S+$ and 11 $S-$, so that there was no evident loss of $S+$ children by $S-$ mothers. We are therefore left with no explanation of the discrepancy other than the suggested chance sampling error.

Pedigree I — A Cree Family

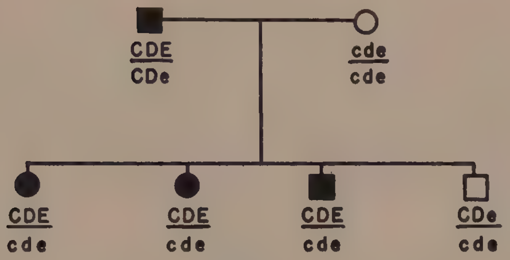

Figure 1

Pedigrees 2 and 3 — Two Blood Families

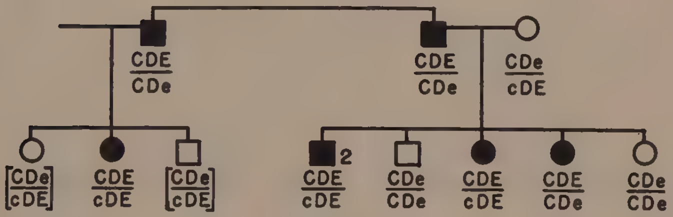

Figure 2

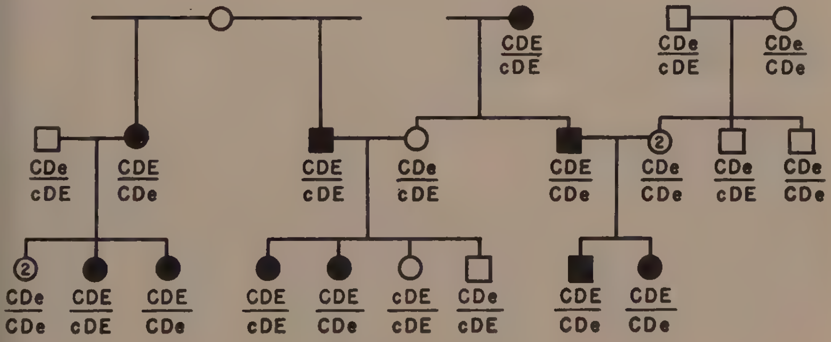

Figure 3

■ ● = Chromosomes *CDE* present, phenotype *CCDEe* being interpreted as genotype *CDE.CDe*, and phenotype *CcDEE* as genotype *CDE.cDE*. Two individuals, shown in square brackets, in F_1 of pedigree 2 are of phenotype *CcDEe*, for which the most common genotype in this population is *CDE.cDE*. One or both could be *CDE.cde* or *CDe.cdE*, on possibly *CDE.cDe* or *Cde.cDE*. The figure "2" in a pedigree indicates two children of the same sex and phenotype. The wife in the Cree family is White.

The *Rh* chromosomes *cDe, cde, Cde, cdE, CDE* and *CdE*

As stated above some of the families were studied in an attempt to prove the presence of the rare *Rh* chromosomes. We were able to identify only *cdE* and *cde*. We have now identified *cdE* in 4 Indian tribes: Blood, Sarcee, Stoney and Kootenai, while Matson, Koch and Levine ('54) isolated it in the Chippewa Indians in Minnesota. We think it likely that the chromosome *cde* is of White origin in the Indians we have studied. The chromosome *CDE* was not recognized in a genotype that would distinguish it from *CdE;* however the chromosome is assumed to be *CDE* rather than *CdE* since we have been able to identify the genotype *CDE.cde* in three families in other Indians of Canada. The pedigree of one of these, a Cree family, is set out in Pedigree I, figure 1. The chromosome assumed to be *CDE* rather than *CdE* was present in at least 24 of 42 descendants of 5 individuals. The pedigree of two of the families are set out in Pedigrees 2 and 3, figures 2 and 3.

SUMMARY

Family studies of the inheritance in the Blood Indians of the blood group and Secretor genes were carried out. The inheritance proved to be according to expectation save in the *S-s* system. The divergence from expectation in this system was thought most likely to be due to a chance sampling error. Of the rare *Rh* chromosomes only *cdE* and *cde* were isolated. As between the chromosomes *CDE* and *CdE*, which could not be distinguished from one another, the former was assumed on the basis of previous experience, and traced through several generations.

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THE ESTIMATION OF AGE AND SEX OF PREADOLESCENT CHILDREN FROM BONES AND TEETH

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The diagnosis of age of living children

In a previous paper (Gleiser and Hunt, '55), the authors presented data on the calcification and eruption of the permanent mandibular first molar. Dental calcification has the great advantage of being conveniently ascertainable from radiographs of a child's jaws at any age. Although tests of the equivalence of radiographic stages with extracted teeth have not yet been carried out, potentially the teeth themselves could be used for these assessments, especially those from skeletal material.

One of the problems which sometimes arises in the identification of a living child is the diagnosis of his chronological age from the calcification of his bones or teeth. On the basis of the dentition, three related estimates of dental age are now available. One estimate can be made from the numbers of teeth visible in the oral cavity (Cattell, '28; Robinow, Richards and Anderson, '42; Nanda, '54). A second, more limited estimate, can be based on our schedule of calcification of the permanent mandibular first molar (Gleiser and Hunt, '55). A third kind of estimate is based on the schedule of calcification of the dentition as a whole, as depicted in the table of

Schour and Massler ('41). The first two estimates take account of the sex of the child: whereas the third table presents dental maturation as though no sex difference occurred in its timing.

Schedules of eruption of the teeth in man are an important part of this kind of assessment. For the clinical emergence of the deciduous teeth, convenient data can be found in Robinow, Richards and Anderson ('42), and in Meredith ('46). For the permanent dentition exclusive of the third molars, the charts of Hurme ('48) can be recommended. These standards are especially useful for American Whites.

For non-Whites, no such adequate standards are yet available, although it is known that their permanent teeth show some tendencies toward early emergence (Steggerda and Hill, '42; Hurme, '46; Garn and Moorrees, '51). Even less is known of specific racial patterns of dental calcification, although the findings of Saito ('36) on the calcification of the roots of the permanent mandibular first molar in Japanese children seem to resemble our data on American White children from Boston, Massachusetts.

Bone age in children may be estimated by many methods. The presence or absence of osseous centers in several body regions may be noted and compared with standards such as those in Sontag and Reynolds ('45), Flecker ('42), Pyle and Sontag ('43), or Harding ('52). In the intact body, exhaustive studies of osseous centers may require a prohibitive number of radiographs. Less precise, but often more practicable methods of regional assessment may be employed. For the hand, suitable standards include those of Todd ('37), Flory ('36), and Greulich and Pyle ('50).

A laboratory where identification is routinely carried out should have publications such as the foregoing on hand.

The sexing of immature skeletal remains

The determination of sex from the skeletal remains of children is notoriously difficult and uncertain, but is of interest both in medico-legal applications and in the study of skeletons from archaeological sites. Improved diagnoses can be based on the fact that the sex difference in dental maturation is far less than that occurring in the skeleton. By whatever criteria are feasible, concurrent estimates of dental age and bone age are made for the remains. These estimates make it possible not only to sex the skeleton, but also to improve the diagnosis of its age at death.

A preliminary test of this method was made, somewhat unrealistically, on radiographs of living children. Problems of applying these techniques to skeletal remains will be considered later in this paper.

The radiographic test is based on a lateral jaw film and a standard developmental film of the hand. On the dental radiograph, the developmental stage of the permanent mandibular first molar is recorded. For a tooth with "two-thirds of the root completed," for example, the mean age for boys of our Boston series would be 84.3 months (7.0 years). For girls, the estimate would be 80.7 months (6.7 years). An assessment of bone age should be made from the atlas of Greulich and Pyle ('50) on male standards, and another from female standards. In the foregoing case, if the "male bone age" were 7 years, the equivalent "female bone age" would be about 5.6 years.

For this imaginary child, the dental and osseous ages by male standards agree closely: while by female standards they diverge by more than a year. Its sex would therefore be diagnosed as male, and its age as 7 years.

Efficiency of the method

The preceding techniques were applied to data on living children in order to determine their efficiency in estimating both sex and age. First, linear equations were calculated by the use of least squares (Arkin and Colton, '39) to represent sex differences in both dental and osseous maturation. Hurme ('48) has published means for the clinical emergence of all permanent teeth except the third molars, and the equation computed from his means fits the sex difference in the calcification of the permanent mandibular first molar as well. Where y equals the age of girls, and x that of boys, the equation is: $y = 0.95x$.

An equally simple equation for the preadolescent sex difference in skeletal maturation of the hand was calculated by using two copies of the Greulich-Pyle atlas. The male standards at or below 12 years 6 months were read from one atlas according to the female standards in the other, and the following equation of sex difference obtained: $y = 0.80x$.

In other words, with increasing age, boys and girls diverge much more rapidly in skeletal maturation than in the development of the permanent teeth.

In an earlier paper (Gleiser and Hunt, '54), the calcification of the permanent mandibular first molar was studied from longitudinal data on Boston White children. Doctor S. I. Pyle has also derived the skeletal age of the hand from radiographs of these children, using the Greulich-Pyle standards. This series of children are among the group who have been investigated by members of the staff of the Harvard School of Public Health and the Forsyth Dental Infirmary for Children, under the supervision of Professor Harold C. Stuart.

Using the two least-squares formulae, the dental and bone ages for the *inappropriate* sex of each child were calculated at the chronological ages of 2, 5 and 8 years. The sex of the child was then diagnosed as the one in which the bone and dental ages agreed most closely. The results of this attempt to sex these children are presented in table 1.

Table 1 indicates that even at the age of two years, this method of sexing is worth the effort. Its efficiency improves with age, as might be expected from the increasing absolute divergence of skeletal and dental maturation in the two sexes.

The diagnosis of chronological age

If the sex of a child is unknown, the equation of the sex difference in ossification of the hand shows how inaccurate a diagnosis of age may be from this region alone. On the average, the age of a girl diagnosed by male standards of ossification will be about 20% younger than her true chronological age.

When sex has been ascertained from osseous and dental maturation, it is of some interest to find out how accurate the

TABLE 1

Ascertainments of sex in children at 2, 5 and 8 years of age

SEX	AGE	N	SEX CORRECT	SEX AMBIGUOUS	SEX INCORRECT	% CORRECT
Boys	2	17	13	1	3	76
	5	17	15	1	1	88
	8	14	11	1	2	79
Girls	2	16	11	0	5	69
	5	16	10	0	6	63
	8	13	11	1	1	85
Both sexes combined	2	33	24	1	8	73
	5	33	25	1	7	76
	8	27	22	2	3	81

TABLE 2

Bone and dental ages of children sexed according to calcification, compared to the total series assigned to correct sex

AGE	SEX DIAGNOSED FROM CALCIFICATION					TRUE SEX				
	N	Bone age (hand)		Dental age		N	Bone age (hand)		Dental age	
		Mean	S.D.	Mean	S.D.		Mean	S.D.	Mean	S.D.
			"Boys"					Boys		
2	18	1.84	0.39	2.03	0.36	18	1.87	0.37	1.95	0.35
5	21	4.61	0.69	5.15	0.54	18	4.53	0.66	5.13	0.61
8	12	7.53	0.82	7.68	0.88	14	7.66	0.85	7.61	0.73
			"Girls"					Girls		
2	14	1.99	0.30	1.88	0.24	16	1.94	0.34	2.00	0.32
5	11	4.85	0.73	5.14	0.34	16	4.67	0.70	5.12	0.41
8	13	7.74	0.64	7.57	0.47	15	7.63	0.68	7.75	0.48

diagnosis of chronological age will be. The ages of those "diagnosed as male" were estimated using male standards, and those "diagnosed as female" by female ones. Table 2 presents the means and standard deviations of bone and dental ages at the true chronological ages of 2, 5 and 8 years. By comparison, equivalent data are presented for the entire group according to their true sexes.

Table 2 indicates that when the sex of a child is diagnosed from osseous and dental calcification, his chronological age can be estimated about as accurately as though his true sex were known. In general, the calcification of the permanent mandibular first molar is slightly more efficient as a predictor of chronological age than is the ossification of the hand.

Systematic errors, however, may be expected in applying many of the current developmental standards to unknown children. The Boston children in the present series, for example, tend to mature late by the standards of Greulich and Pyle, which were based on a sample of children from Cleveland, Ohio. Even greater delays in maturation can be expected in children growing up in adversity: whether because of diseases, climatic stress, or poor nutrition. An example of such late maturation was found by Weiner and Thambipillai ('52) in radiographs of the hand in a group of West African Negro children.

Possible improvements in the method

As mentioned previously, the foregoing evaluation of age and sex of children was done on radiographs of the living, and therefore be regarded as a somewhat unrealistic test of its efficiency on skeletal material. In transferring it to immature skeletons, a number of modifications in the technique would probably be desirable.

From the permanent mandibular first molar alone, dental age can be estimated up to 8 or 9 years. If standards were perfected for either or both of the permanent second molars, the dental age could be determined up to 14 or 15 years. Dental calcification is now being studied in several ongoing investigations of human physical growth in the United States, so that these standards should soon be available. Standards for several additional classes of teeth might also improve the precision of estimation of dental age.

Although comparisons of osseous and dental maturation appear to be the method of choice in sexing younger children, in the adolescent, a much more accurate diagnosis of sex can probably be made by Washburn's techniques (see Washburn, '48, '49; and Hanna and Washburn, '53), especially when fusion has begun in the acetabulum.

In making assessments of dental age from skeletal remains, the problem of preservation is generally not critical, and radiographs or studies of the teeth themselves should not ordinarily be difficult. In diagnosing bone age, however, the skeleton of the hand is by no means ideal material. These bones are small and easily destroyed, and the comparison of these fragments with standards in a radiographic atlas may be virtually impossible.

More suitable parts of the skeleton for determining bone age should resemble the hand in that a clear sex difference occurs in their rates of maturation. These regions should also include large epiphyses, since these major centers are relatively apt to be preserved in exposed or buried skeletons. The most suitable single region may well be the knee, and a radiographic atlas of this region has just been published by Pyle and Hoerr ('55). In further tests of this method on immature skeletal material of known age and sex, the dentition and knee would almost certainly be one of the best combinations of sites.

SUMMARY

The determination of sex from the skeletal remains of preadolescent children is notoriously difficult. A possible improvement of such diagnoses is based on the fact that the sex difference in dental maturation is slight, so that for equivalent stages of development of the permanent teeth, the

average age of a girl is about 95% of that of a boy. For the maturation of the bones of the hand, at a given stage, a girl will be about 80% as old as a boy.

On the basis of these equations, concurrent estimates of bone and dental age by male standards should agree closely if the remains are those of a boy, but should be more divergent if female standards are applied. The opposite is usually true if the remains belong to a girl. If bone and dental ages are assessed for the remains by the standards of both sexes, the sex for which the standards agree best is considered to be the correct one.

Somewhat unrealistic tests of this method were completed on dental and skeletal (hand) radiographs of living children from a longitudinal growth study at the Harvard School of Public Health. At two years of age, 73% of 33 children were assigned to the correct sex. At 5 years, 76% were correctly diagnosed. Eighty-one per cent of 27 children in this group were accurately sexed at 8 years of age.

In an unknown immature skeleton, a lateral radiograph of the jaws and an examination of osseous development make the determination of its age at death somewhat more accurate. In fact, this age can be estimated about as precisely as though its true sex were known.

In applying this method to skeletal materials, it would usually be impracticable to estimate bone age from the bones of the hand. A radiographic atlas of the knee by Pyle and Hoerr ('55), however, may make the method more widely useful if applied to the teeth and knee alone.

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THE EAST AFRICAN VERTEBRAL COLUMN

A STUDY IN RACIAL VARIABILITY

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EIGHT FIGURES

In the past, comparative studies of the vertebral column have suggested that African derived material has more morphologic variability than is found in other races (Todd, '22; Lanier, '39). Shore ('30) refers to the South African Bantu as strikingly unstable with "an incidence of each abnormality higher than is recorded in other records." The present study was used to test the validity of this widely held belief.

The pattern of variability in East African skeletal material indicates that there is a difference in the frequency with which individual vertebral variations occur. When this pattern is compared with data from other races it is found that the idea of the extreme "plasticity" of vertebral structure in African material requires some modification.

As much confused discussion has centered around the etiologic causes of many of these variations, opportunity is also taken to discuss these, using the available comparative data from human and animal experimental studies.

MATERIAL

A total of 206 presacral vertebral columns from the anthropological collection in the Department of Anatomy, Makerere College, were examined. Differences in the total numbers of various characteristics are due to exclusion of damaged vertebrae, or vertebrae showing obvious pathologic bony changes.

This collection reflects certain social patterns found locally. Kampala attracts a large number of migrant laborers from the surrounding countryside up to 400 miles distant. A large proportion (Bahuti) come from the neighboring territory of Ruanda-Urundi (in the Belgian Congo). These tribes form the bulk of the present material, whereas the local Ganda (living in Buganda, Uganda) are only a small proportion of the material. (See table 1.) Subsequently this collection will be referred to as "East African" skeletal material.

TABLE 1

Ethnologic grouping of East African skeletal material

ETHNIC GROUPING	NUMBER OF SKELETONS
Bahuti [1]	110
Other Bantu [2]	56
Nilotic [3]	10
Nilohamitic [4]	9
Sudanic [5]	5
Unknown	16
Total	206

[1] From Ruanda-Urundi (Belgian Congo).

[2] Composed of: Nkole = 12: Ganda = 9: Nyoro = 7:
Toro = 6: Kiga = 6: Zinza = 4:
Soga = 3: Gishu = 3: Ziba = 3:
Haya = 2: Kikuyu = 1.

[3] Composed of: Lango = 6: Alur-Luo = 4.

[4] Composed of: Teso = 6: Kakwa = 2: Sebei = 1.

[5] Composed of: Lugbara-Madi = 5.

The ethnic grouping of table 1 is that in use by the East African Institute of Social Research, Kampala. This classification may or may not have physical anthropological significance. East Africa as a whole, and this part in particular, has been the meeting place of many streams of culture. Much admixture of stocks has occurred, and attempts to correlate the so-called basic physical types of Africa with the tribal divisions found in this population are both unsound on theoretical grounds and usually unattainable in practice.

One hundred and thirty-six, or about two-thirds of the skeletons are from individuals under 40 years of age, whilst the age is unknown in 44 of the remainder. The age distribution is an approximation, for it is usually impossible to get an accurate age from a patient, and the age given is generally the estimate of the Hospital Admissions Officer. A possible reason for the preponderance of the 20 to 40 age group is that these often represent the migrant laborers from Ruanda-Urundi unclaimed because they fall ill far from their clan home.

There are 27 female skeletons and 179 male skeletons in this series, and this distribution reflects the small number of women admitted to the hospital compared with men.

Pattern of variability

The incidence of the following characters was studied:

1. Numerical variation.
2. Configuration of cervical spinous processes.
3. The disposition of thoraco-lumbar (zygopophysial) articular facets.
4. Asymmetry of facets.
5. Sacralization of the last lumbar vertebra.
6. Spina bifida.
7. Spondyloschisis.
8. Vertebral fusion.
9. Additional ribs.

1. Numerical variation. It is more difficult to be certain of a true numerical reduction than addition, but the possibility of loss is minimized by great care and attention to detail during preparation.

The modal number of 24 presacral vertebrae appeared in 85% of the columns. Reduction to 23 presacrals occurred in 3.4%, whilst addition to 25 was present in 11.6% of the 206 columns examined. Four numerical variations occurred in the 27 female vertebral columns (14.8%), whilst 28 occurred among the 179 male columns (15.6%), which is not a significant difference.

Additional thoraco-lumbar vertebrae, making a total of 25 presacral pieces, occurred 24 times. In 9 of these the additional vertebra was thoracic in type whilst separate vertebra 25 (6th lumbar) occurred 15 times. In one case the 6th lumbar vertebra was associated with reduction in the number of thoracic vertebrae making the model 24 presacral vertebrae. In all other columns with additional lumbar segments, the cervical and thoracic regions retained their usual number of vertebrae. The occurrence of three vertebral anomalies in the additional lumbar vertebrae is noteworthy.

Reduction in the modal number of presacral vertebrae to 23 occurred once in the cervical region, and 5 times in the lumbar region.

2. *The configuration of the cervical spinous processes.* The appearance of the spinous processes as seen in the norma verticalis was examined and they were classified on the basis of the scheme suggested by Shore ('31). The processes were broadly grouped into those showing bifidity and those not showing bifidity. Shore's criterion, that any spinous process having a dorsal groove deeper than 1 mm was "bifid," was adopted in order to make comparison with his and other workers' data more exact. The two main groups were further subdivided as follows:

(a) *Bifid cervical spinous process.*
   1. Bifurcate, with divergent alae (fig. 2).
   2. Cleft, with non-divergent or parallel alae (fig. 3).

(b) *Non-bifid cervical spinous process.*
   1. Acinate — pointed and tapering.
   2. Obtuse — blunt ended and squat.
   3. Pediculate — studlike.
   4. Clavate — long and clublike.

In the 1162 East African cervical vertebrae examined, 55% had bifid spinous processes and 45% had non-bifid processes. Of those termed "bifid" the bifurcate was much the most common (83%), although the length of the alae and the angle they made with each other varied enormously. In some cases the alae were long and formed nearly a right angle with each other. In other cases the bifurcation was definite but the alae were only a few millimeters long and were curved and ill formed (fig. 4). The "cleft" type occurred in 17% of bifid forms, and were remarkable for their similarity. The alae were parallel to one another, were smooth, straight and usually long. No attempt was made to determine the incidence of the non-bifid types although all the types mentioned by Shore were seen. In 10% of the columns the cervical vertebrae C2 to C7 all had non-bifid spinous processes. In 3% all these (C2–C7) vertebrae were bifid. In these a few had all bifurcate, or all cleft processes. But in most columns some cervical vertebrae had bifurcate, some had cleft and some had non-bifid spinous processes.

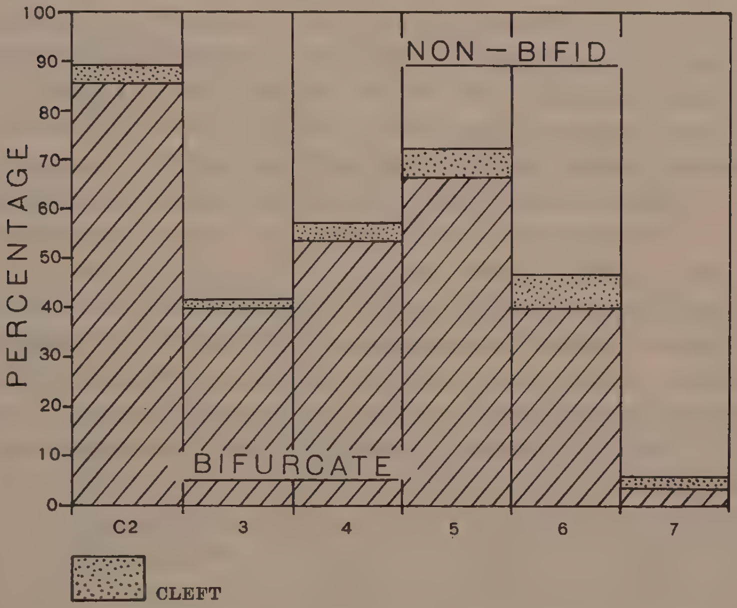

Fig. 1 Distribution of bifid character in cervical spinous processes.

Distribution of bifidity: Bifid spinous process occurred most commonly in the *axis vertebra* (C2), where it was almost universally found. The spinous process of the axis was unique among vertebrae because of its characteristic and variable forms. Viewed in the norma dorsalis, the tip of the spinous process of the axis was variously moulded, (Y-shaped, V-shaped or T-shaped, or quite irregular in outline). The *fifth cervical* was the second commonest vertebra showing bifid characters, whereas the *seventh cervical* was bifid only rarely. Figure 1 indicates the pattern of distribution of the two main types of spinous process in the cervical spine.

3. *Articular (zygopophysial) facet disposition in the thoraco-lumbar transitional region.* It is said that the nineteenth vertebra bearing both thoracic and lumbar type articular (zygopophysial) facets is the most common thoraco-lumbar junctional vertebra, (Dwight, '07; Terry, '43). In the junctional vertebra the superior articular facets are of a thoracic type, being arcs of a circle the center of which is anterior to the vertebral canal, whilst the inferior articular facets are lumbar in type, being arcs of a circle the center of which lies posterior to the vertebral canal.

In one hundred and fifteen columns the vertebrae in this transitional region were examined in the norma verticalis, the plane of inclination of the articular facets were noted, and the vertebral level at which the lumbar character of the superior facet begins was determined. Apart from the frankly lumbar and thoracic planes, intermediate positions were classed in an arbitrary way into those tending towards the typical lumbar and those tending towards the typical thoracic positions, and were counted as such.

In 51.3% of the columns the lumbar character of the superior articular facet began at vertebra 20 (L 1), and in 43.5% it began at vertebra 19. In 5.2% it began at vertebra 21. Of these, 4 out of the 6 columns were counted as having 6 lumbar vertebrae, because of other criteria, (shape of body, shape of spinous process, absence of rib).

4. *Articular facet asymmetry* frequency was determined. The superior articular facets of a given vertebra were examined, and classified as asymmetrical if, for example, the left facet tended to the lumbar type, whilst the right facet tended to the thoracic. Such asymmetry was found 28 times

(24.3%). It was almost confined to vertebra 19 (T 12), in only one case did it occur in vertebra 20 (L 1). In 18 cases the right side only was affected, and in 10 cases the left only. (fig. 5).

5. *Sacralization of the last lumbar vertebra.* This occurred in vertebrae 24 (L 5) and 25 (L 6), both bilaterally and unilaterally. In 200 columns the total incidence (in 24 and 25) was 11%, (22 times). In vertebra 24 sacralization occurred in 6.5% of 185 skeletons, whilst in vertebra 25 it occurred in 66% (10 out of 15 skeletons), or with about 10 times the frequency. Extensive articulation of a sacral type of transverse process with the sacrum was the usual form, but complete fusion into the sacrum of the transverse processes of vertebra 24 occurred in two cases. Sacralization was usually bilateral (16 times), but when it was unilateral it was only found on the left, never on the right.

6. *Spina bifida* was the most commonly found vertebral anomaly, and occurred in 10% of columns. It corresponds to the spina bifida occulta of the clinicians, and is morphologically a non-fusion of the developing halves of the posterior vertebral arch. In this series it occurred most commonly in the atlas vertebra, but was also found throughout the vertebral column (fig. 7 and table 2).

7. *Spondyloschisis* (''pars interarticularis'' lesion, separation of the lamina). This lesion is a separation of the spinous process, laminae, and the inferior articular facets from the rest of the vertebra occurring on one or both sides. In the present series it was always bilateral and usually lumbar in position. In apparently normal lumbar and thoracic vertebrae the site of separation was frequently found to be perforated by large vascular foramina, (fig. 6 and table 2).

8. *Non-pathological vertebral fusion.* A synostosis or clean fusion of articular facets, laminae, and sometimes bodies occurred in 4 cases in widely varying regions of the column. The bone looked normal in every respect and there was no evidence of bone disease (fig. 8 and table 2).

9. *Additional ribs.* One case of unilateral cervical rib, 3 cm in length, was found on the right side of a seventh cervical vertebra, and one case of bilateral lumbar ribs, 4 cm in length, was found on an otherwise typical first lumbar vertebra.

TABLE 2

Distribution of certain anomalies in the vertebral column in the East African skeletal material

VERTEBRA	INCIDENCE OF SPINA BIFIDA	INCIDENCE OF SPONDYLO-SCHISIS	INCIDENCE OF NON-PATHOLOGIC VERTEBRAL FUSION	INCIDENCE OF ADDITIONAL RIBS
C 1	8			
2			1	
3				
7	2			1
T 1	3		2	
2				
3	1	2		
5		1		
11	2			
12		1		
L 1	1			1
4		2	1	
5	1	2		
6	2	2		
Total incidence	10%	5%	2%	

DISCUSSION

1. *Variations in the number of presacral vertebrae:* The modal number of the human vertebral column is 24 presacral vertebrae. This is usually constituted as represented by the formula $\mathrm{C}^{\underline{7}}$, $\mathrm{Th}^{\underline{12}}$, $\mathrm{L}^{\underline{5}}$.

The constancy of this formula is a typically human characteristic, but variations from it occur differing in their frequency according to race. Willis ('23) found this modal formula in 95.8% of North American vertebral columns, and on this basis wrote that "the stability of the thoraco-lumbar column is a human characteristic irrespective of stock or sex." However, other studies cast doubt on this statement, for a 12% variation on the modal 24 presacral vertebrae was found in Eskimos (Stewart, '32) and North American Negro (Lanier, '39) skeletons, whilst in the East African series the incidence of numerical variations is the highest yet recorded, 15%, (table 3).

TABLE 3

Racial comparison of numerical variations in the vertebral column

RACE	AUTHOR	NUMBER OF COLUMNS EXAMINED	PRESACRAL VERTEBRAE 25	24	23
			%	%	%
White ♂	Willis '23	557	4.2	95.1	0.7
Negro ♂	Willis '23	185	4.9	93.6	1.6
White ♂	Lanier '39	100	2.0	95.0	3.0
Negro ♂	Lanier '39	100	7.0	88.0	5.0
Eskimo	Stewart '32	217	12.0	88.0	0.0
South African Bantu	Shore '30	82	5.0	95.0	0.0
East African	Allbrook '54	206	11.7	84.9	3.4

An additional thoracic vertebra is a frequent finding (6.6% in Europeans by Fischel, and 6.1% in Japanese by Hasabe). These are comparable to the numbers found in the East African series (4.6%). Additional lumbar vertebrae are likewise common and were found in 8.4% of the columns examined.

Reduction to 11 thoracic vertebrae was seen once associated with 6 typical lumber vertebrae, (not altering the modal number of 24 presacral vertebrae). Reduction to 11 thoracic vertebrae is rare, for Hasabe found it in under 1% of 2112 Europeans, and in 1% Japanese, although Schultze reported a 5% incidence in 161 negroes. Reduction to 4 lumbar vertebrae here occurred 5 times (2.4%) and in every case the 24th vertebra was assimilated into a 6 piece sacrum.

Reduction of the cervical vertebrae to 6 is a very rare occurrence in any mammal, for this region is numerically one of the most constant in the vertebral column. Reduction to 6 cervical vertebrae was found once in this present series in a column of 23 presacral vertebrae.

Influence of tribe and sex on numerical variations: Analysis failed to show any significant differences in the incidence of numerical variations caused by tribal origin, or between the main ethnic groups mentioned in table 1. A similar analysis for numerical differences associated with sex failed to demonstrate any significant differences between male and female skeletons. The female series contained 14.8% and the male 15.6% numerical variations. This result supports the contention of Willis ('23) and others that numerical variations are independent of sex, but is suspect because of the small numbers of female skeletons in this series.

Hereditary control of variations: The hypothesis of hereditary control of numerical variations is an old one. Bardeen ('04) after morphologic and embryologic studies stated that "regional variations in the vertebral column is an inherited condition which makes itself manifest early in embryonic development," a conclusion that was supported by the breeding experiments of Frets ('09). In human material the monumental and extensive work of Kühne ('32, '36) using large numbers of vertebral roentgenograms to study the vertebral variations found in a number of families, put this theory on a firm factual basis. Kühne demonstrated a tendency of morphologic variations to vary in the same direction in genetically related individuals. He speaks of a ‘‘caudal shift’’ as a recessive character and a ‘‘cranial shift’’ as a mendelian dominant factor. This work suggested that genetic effects are not concentrated on one vertebra alone. For all the observed variations are said to be explicable on the assumption of one pair of genes producing homoeotic changes in a given region. There is even a strong suggestion from this work that the whole length of the vertebral column may be affected by these genes. But Fischer (’33) thought this homoeotic tendency was controlled by genes producing local acceleration or slowing of growth. By definition homoeotic numerical variations are taken to be, not an increase in the total number of segments (meristic variation), but an alteration in the relative number of segments or vertebrae composing the different regions in the vertebral column. It should be emphasised that because of failure to report the numbers of sacral and coccygeal segments in most human collections it is quite impossible to say whether their numerical variations represent homoeotic or meristic changes.

Direct genetic animal experiments provide strong supporting evidence for the hereditary control of numerical variations. Using roentgenologically controlled rabbit biotypes Sawin (’37, ’45) demonstrated that homoeotic vertebral variations in certain strains may breed nearly true on artificial selection. The evidence here points to a single pair of genes causing a caudal shift in the position of both the thoracolumbar and lumbosacral junctional zones. Likewise meristic variations in the total number of vertebral segments have been studied in the tail of the mouse by Green (’31).

From the anthropologist’s viewpoint these results are of great interest. It seems clear that in both humans and animals numerical variations are genetically controlled. It has been demonstrated that this type of variation is found with a widely differing degree of frequency in many different racial groups (table 3), and it seems very probable that these differences are due to varying gene frequencies in the world population.

2. *The configuration of cervical spinous processes:* Among the standard anatomical works, condensed and simplified descriptions of this feature often give an erroneous impression of the racial differences. Morris ('43) states that "in the coloured races of man the cervical spines are relatively shorter and more stunted than in Europeans and, as a rule, are simple." Frazer ('48) and Grant ('48) both quote Cunningham's (1886) statement regarding racial differences in the spinal processes of the cervical vertebrae, whilst no mention of bifidity as a racial characteristic is made in the textbooks by Buchanan ('46) or Gray ('46).

The anthropoids and fossil man typically have non-bifid cervical spinous processes (Boule and Vallois, '52). The South African Bushman similarly has this type of process in a very high proportion of vertebrae, (93% quoted from Shore, '31). But in other African and African derived material this condition is much less common (ranging from 79% in South African Bantu, to 45% in East African tribes), whilst it is infrequently found in Asiatic and European material (about 26%).

Shore ('31) in his exhaustive morphologic study of the cervical spinous process of South African Bantu, suggested that the Bantu (and Bushmen) are more advanced in a characteristic (bifidity) that is tending to disappear, whilst white races, whose skeletons usually have bifid cervical spines, show more resistance to this change. There seems to be no real evidence one way or the other for this hypothesis.

A detailed comparison of the individual cervical vertebrae indicates certain tendencies common to the racial groups studied and is of taxonomic interest. For example the *axis* vertebra shows bifidity most commonly in nearly all races (excepting the 20 Fuegians studied by Mijsberg in which C4 bifidity was the most frequent), and the seventh cervical is occasionally bifid in most races. There are however tendencies which differ according to racial group. Excluding the few Bushmen skeletons, all the African derived material shows a similar pattern of distribution of the bifid character among the individual cervical vertebrae, although the absolute percentages differ considerably. In the Japanese cervical spines, on the average the more caudal the vertebra, the less likely it is to be bifid. In European material there is a sharp fall in the percentage bifidity at C 6, and complete absence of this character at C 7, (table 4).

Of the different bifid types the "cleft" has a similar incidence (9% of all cervical vertebrae) in the East and South African series, but is more commonly found in Europeans (20%). The "bifurcate" is the usually occurring type in both European and East African material (52% and 45% respectively). But in the East African material this 45% is made up of a large proportion (27%) in which the alar tips are bifurcate only (fig. 4).

TABLE 4

The racial distribution of the % incidence of the bifid character of the spinous process in individual cervical vertebrae (after Lanier, '39)

RACE	C 2	C 3	C 4	C 5	C 6	C 7
East African	92.3	40.6	63.5	72.2	50.2	7.7
American Negro	81	32	43	62	41	1
S. African Bantu	24.3	13.4	26.2	41.5	21.5	0
European	100	91	91	95	71	0
Am. White	97	89	94	97	55	0
Japanese	99	95	91	86	34	0
Fuegians	35	35	90	65	20	0
Bushmen	18.2	0	9.1	16.7	0	0

Differences in the racial configuration of cervical spinous processes and the hypothesis that "non-bifid spines in the lower races indicate a free mobility of the vertebral column" were noted by Cunningham (1886). Von Eggeling ('22) after a study of the skeletal and muscular systems of man and the anthropoids thought that the degree of bifurcation of the spinous processes depended on the posture and mobility of the cervical spine. He emphasised the importance of the attachments of the semispinalis capitis muscle altering the morphology of the spinous processes, and associated the non-bifid condition with poor mobility of the cervical spine.

It is difficult to give credence to this approach in attempting to explain these morphological differences. Doubt can be cast legitimately on any method which in the hands of different experts yields opposite conclusions from similar data. In this case two eminent morphologists reach diametrically opposed conclusions from their study of cervical vertebral morphology. In the present series is found both bifid and non-bifid spinous processes, and many minor variations of each type. But from personal observation it can be stated that these variations cannot be correlated with cervical posture or mobility in living subjects. As in other bones minor differences may well be due to small variations in muscle attachments. Of particular relevance is Grüneberg's ('50) account of variations in shape and length of the vertebral spinous processes in the mouse, where these factors are seen to be genetically determined, although the exact mechanism has not been established. It is not unlikely, therefore, that some similar mechanism is responsible for the main types of variation in the cervical spinous processes described here in man, and that the observed differences in racial incidence of these forms may be attributable to varying gene frequencies in the world population.

3. *Thoraco-lumbar (zygopophysial) facet transition:* The vertebra of transition from the thoracic to the lumbar type of articular facet is variable in most series reported upon, for the transition may occur at vertebra 19 (T 12), 20 (L 1), or 21 (L 2). Table 5 compares 5 different racial groups in this

TABLE 5

The percentage distribution among vertebrae 19–21 of the beginning of lumba articular facets. A racial comparison

VERTEBRA	JAPANESE (Hasabe)	ESKIMO (Stewart)	AMERICAN NEGRO (Lanier)	AMERICAN WHITE (Lanier)	E. AFRICAN (Allbrook)
	%	%	%	%	%
19 (T 12)	19.0	4.9	38	43	43.5
20 (L 1)	77.4	75.3	50	48	51.3
21 (L 2)	3.6	19.8	12	9	5.2

respect, and shows a clear difference between them. In every case the 20th vertebra (L 1) is modal. But the percentage incidence of the 19th vertebra having lumbar facets varies widely from 4.9% in Eskimos to 43.0% in American white and East African skeletons. The 21st vertebra has lumbar facets starting in nearly 20% of Eskimo columns, but in other races this is uncommon. Japanese skeletons have a stable arrangement, for vertebra 20 has lumbar facets in 77%, whilst in Americans (white and negro) and East Africans this figure falls to about 50%. These findings become significant in the light of Kühne's work already cited. For, using his terminology, there appears in the American and East African columns a strong tendency to cranial deviation of this character. This is less marked in Japanese, and in Eskimos is replaced by caudal deviation.

4. *Thoraco-lumbar articular facet asymmetry:* Asymmetry in the articular facets was reported first by Struthers (1875) and was said to be a rare anomaly by Barclay Smith ('02). But Whitney ('26) found it in 5.7% of 139 white males and 4.3% of 69 negro males and thought that asymmetry was an expression of left- or right-handedness. Lanier ('39) on the other hand found asymmetry far more common in both races, possibly because of a more stringent definition of the term. Asymmetry was present in 17% of white males and 14% of American negro males and he concluded that it is more common in white races. But the statistical significance of this result is doubtful and is clearly at variance with the present results, which have a higher incidence of asymmetry than any series yet recorded. Lanier points out that every bilateral variant in the vertebral column studied by him is slightly but constantly more frequent on the right than on the left side. This finding is confirmed in the present study where facet asymmetry is found on the right in 18 out of 28 examples. Lanier suggested as an explanation for this finding that these bilateral variants are phenotypes genetically determined, but

although this may be so, there is no clearcut evidence to support this hypothesis.

5. *Sacralization of the last lumbar segment:* This phenomenon has been described many times using different classifications. For example, Le Double ('12) described 6 degrees, ranging from a minor change in the tip of one transverse process, to full incorporation in the sacrum. It is an attractive hypothesis that sacralization forms part of the total picture of homoeotic variation in the vertebral column, and if this were so, the morphologic classifications would become largely irrelevant (Lanier, '39, '54). Kühne's ('36) work already cited demonstrates from an impressive body of evidence that it is the presence of a sacralizing tendency in the last lumbar vertebra that is of genetic significance, rather than a precise appraisal of the degree of sacralization. Table 6 demonstrates that sacralization of the 24th vertebra was totally absent in Eskimos, and present to a small degree in Japanese skeletons. Comparison with table 5 demonstrates that these are the two races that stand out from the others in that the 19th (T 12) vertebra is rarely the site of the beginning of the lumbar type facets. This is most striking in the case of the Eskimo skeletons where the 21st vertebra had this character in nearly 20% of cases, whereas sacralization of the 24th vertebra was never seen. The great frequency (66%) with which bilateral partial sacralization of the separate 25th vertebra occurs is of interest but is what might be expected on the hypothesis of genetic control of homoeosis.

6. *Spina bifida:* or non-fusion of the vertebral porterior arch was found in 10% of the East African columns examined Table 6 indicates that this finding is also common in the South African Bantu, but is rare in North American material (both Negro and White).

The distribution of the variation in the vertebral column is of interest (table 2). All regions were affected, but i occurred most commonly in the atlas vertebra, where in addition to the usual posterior arch spina bifida or dyssymphysis one case of anterior arch dyssymphysis of the atlas, and two of completely separated halves of the atlas were found. Mice show several genetically determined examples of atlas and axis dyssymphysis (Grüneberg, '50), but the common form seen is in the anterior arch, rather than the posterior dyssymphysis or spina bifida so frequent in man.

7. *Spondyloschisis* (separate neural arch, "pars interarticularis" lesion). This variation was described 100 years ago by Kilian (1854) who gave an account of its morbid anatomy and posed the etiologic questions which have stimulated research and debate ever since. Is the lesion a congenital ossification deficiency or is it acquired, in the nature of a stress fracture of bone? Examination of embryologic and fetal material by such workers as Mall ('05), Willis ('31), Batts ('39), Rowe and Roche ('52) have failed to bring to light examples of the anomaly at this period in life, and according to the latter's review neither has it been found in neonates or in young children. In Eskimo skeletons there is an increase in the incidence from 4.3% at 6 years to 16.9% at 24 years of age, when the incidence remains steady until it increases to 33.9% after 40 years of age (Stewart, '51).

TABLE 6

Comparative racial incidence of three characters. The figures are the percentage occurrence rate reported by authors previously cited

RACE	SACRALIZATION OF 24TH VERTEBRAE	SPONDYLOSCHISIS	SPINA BIFIDA
E. African	6.5	5.0	10.0
S. African Bantu	1.2	6.0	18.2
N. American White	8.0	6.5	1.0
N. American Negro	6.0	5.5	1.4
Eskimo	0.0	28.0	6.0
Japanese	2.3	10.0	
European		5.0	

A clear-cut embryologic defect is therefore most unlikely as an etiologic cause. But on the other hand if a purely traumatic etiology is postulated, there are several difficulties to be explained. What is the explanation of the widely differing ethnic and sex incidence, which is such a striking feature of this condition? (see table 6). What is the explanation of the fact that different regions of the column are affected in particular races? For example in the present series the lesion was found in both thoracic and lumbar regions, in North American columns it was confined to the lumbar region, but in Japanese and Eskimos it also occurred in cervical vertebrae.

It is a common fallacy to assume that a genetically determined defect is also congenital. In fact the overt effects may remain hidden and only become obvious later in life. In this connection it is significant that Grüneberg (personal communication, '54) has found a lesion developing in a pure strain of mice which is comparable to the human lesion of spondyloschisis, and which is without doubt genetically determined. Willis ('31) considered that this lesion was an ossification failure at the narrow zone between the superior and inferior facets, the pedicle and the lamina (the pars interarticularis). Failure at this very narrow point was brought about by the penetration of large nutrient blood vessels. These were present in East African skeletons as denoted by the occasional presence of large or small nutrient foramina piercing the "pars interarticularis." It is therefore suggested that these blood vessels are phenotypes, but that the separation itself follows indirect strains on the back during violent muscular exercise during adolescence.

8. *Non-pathological vertebral fusion* was observed 4 times in widely differing parts of the column (table 2). Le Double ('12) mentions this as a rare thoracic anomaly, whilst Borovansky ('28) describes a number of cases of fusion in the cervical spine (usually between C2 and C3), and attributes this to normal limitation of movement at this point. This hypothesis is not supported by roentgenologic studies of the cervical spine, and the etiology of this condition remains unknown although a genetic basis for it would not be altogether surprising as vertebral fusion is a common finding in some mammalian species. Atlanto-occipital, and atlanto-axial fusion

have been fully described in the past (Macalister, 1893; Elliot Smith, '07; Cave, '30), but no example was found in the present series.

9. Cervical and lumbar ribs: Barbosa Sueiro ('33) recorded an incidence of 2.0% cervical ribs in 1527 columns collected from the literature. In the present investigation additional ribs were rare, for unilateral cervical rib (C7) occurred once, and bilateral lumbar ribs (LI) also occurred once. The genetics of commonly occurring rib variations in rabbits has been fully described by Sawin ('45).

Racial comparison of vertebral variations: In the vertebral column the dividing line between morphologic variation and the structural changes of clinically significant disease is often hard to define. A typical example of this is the discussion cited above on the etiology of spondyloschisis, a condition which may quite conceivably have a genetic origin. But because of their clinical unimportance many human morphologic variants have been ignored and their racial incidence is therefore unknown. In fact both clinically significant and insignificant variants may be clear examples of genetically controlled polymorphism in the ventral column. For example, during this study many different variations were found in the human atlas vertebra of which the following may be cited: posterior arch venous foramen, ossified oblique ligament, posterior tubercle resembling spine, incomplete fusion of the anterior or posterior arch, incomplete or duplicated transverse foramina, and canalization of the lateral mass. Similarly, it was found that 25% of vertebral columns had open cervical transverse foramina in one or more vertebrae. Neither of these features has any known clinical significance, but both have a known parallel occurrence in laboratory rodents where they have a well-defined genetic basis. There is therefore indirect evidence that the variations described are partly or wholly genetically controlled, and that in the human vertebral column the racially variable polymorphism may be an expression of differing genetic patterns.

The general proposition that African derived material shows extreme variability (Shore, '30) needs some modification in the light of the present results. For although in this material the incidence of some variations is high (e.g. numerical variations and spina bifida), in others, (e.g. spondyloschisis, sacralization of the last presacral segment etc.) it is comparable with that found in other skeletal material from different racial groups.

SUMMARY AND CONCLUSIONS

Certain features of a series of 206 East African vertebral columns are described.

1. Numerical variations occurred in 15% of columns. This high incidence is compared with that found in other races, and is discussed in relation to Kühne's roentgenologic work in humans, and experimental genetic work in laboratory animals.

2. The configuration of cervical spinous processes is unlike that found in similar European material; bifidity, of which there were several different types, was present in 54.5%. The racial incidence and distribution in the column of these is analysed. Various theories explaining these morphologic differences are examined, and evidence suggesting their genetic basis is produced.

3. The articular facet planes in the thoraco-lumbar transitional zone were examined and were found to be comparable with American (white and negro) skeletons, but different from Eskimo and Japanese.

4. Facet asymmetry in a transitional vertebra was found in 24% of columns. This is more frequent than in other races. The possible significance of this is discussed.

5. Sacralization of the last lumbar vertebra occurred in 6.5% of columns containing 24 vertebrae, and in 66.6% of columns containing 25 vertebrae.

6. Certain other anomalies are described (spina bifida, spondyloschisis, vertebral fusion, and additional ribs). Their incidence is noted and compared with that found in other

races, and with what is known of their morphogenesis in laboratory animals.

The foregoing data is interpreted by the conception of genetic control of variations being applied to human vertebral skeletal material.

It is pointed out that the present findings suggest that the statement that African material shows extreme variability needs modification.

ACKNOWLEDGMENTS

The author is greatly indebted to the following gentlemen for their stimulating criticism and advice during the studies summarized in this paper; Professor A. Galloway, Professor A. J. Cave, Doctor Hans Grüneberg, and Doctor J. T. Aitken. To Mr. T. N. Salthouse the author is indebted for many fine bone photographs, a few of which illustrate this paper.

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PLATE 1

EXPLANATION OF FIGURES

2 Cervical vertebra. Bifurcate spinous process.

3 Cervical vertebra. Cleft spinous process.

4 Cervical vertebra. Bifurcate process, alae short and malformed.

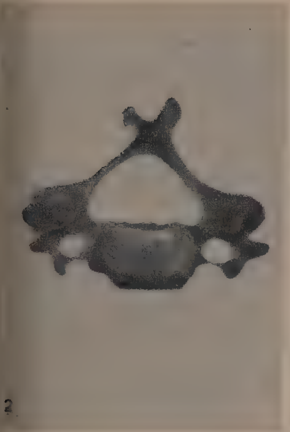
5 Lumbar articular facet asymmetry.

6 Spondyloschisis.

7 Spina bifida.

8 Non-pathologic vertebral fusion.

PLATE 1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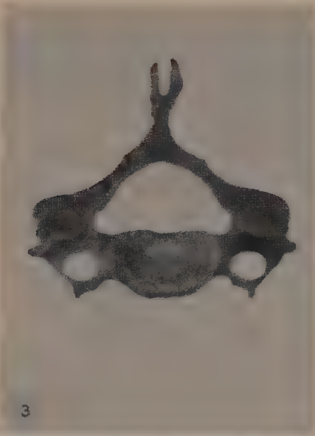
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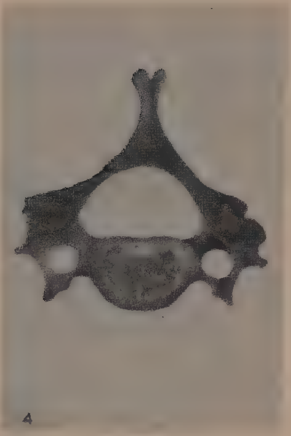
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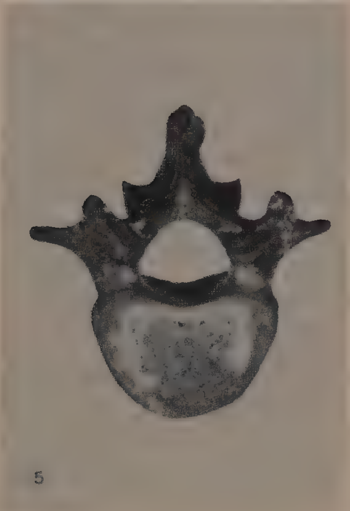
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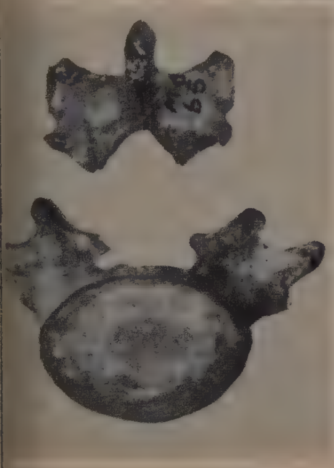

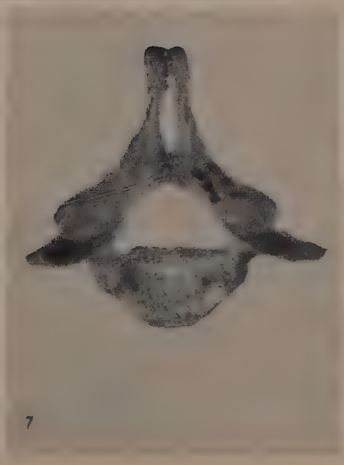
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8

AN X-RAY STUDY OF GROWTH CHANGES IN THE BASE OF THE SKULL[1]

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Before the study described in the previous paper (Zuckerman, '55) was begun, an attempt was made to use laminographic x-rays in order to follow growth changes in the basicranial axis. Observations were made on a total of 65 individuals ranging between two and one-half and 24 years of age. The x-rays were taken as nearly as possible through the mid-sagittal plane of the head.

The exact positions of the pituitary point and of the anterior margin of the foramen magnum were relatively easy to mark on the films. Some difficulty was, however, experienced in defining the nasion, the prosphenion and the basion. All points were therefore marked independently by three workers, and a tracing made of each set. It was found that "observer error" did not significantly affect the measurements under consideration.

On the other hand, the x-ray method, as used in this study, appears to be insufficiently sensitive to reveal all the age changes that are disclosed by an analysis of actual skeletal dimensions. This is apparent from table 1, which compares cranial dimensions as measured from x-ray pictures of living subjects, with corresponding measurements taken on the collection of skulls discussed in the previous paper. By "x-ray dimension" is meant the cranial dimensions of the

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TABLE 1

Age changes in the base of the skull, as measured from x-rays. (Pituitary point as anterior limb of basicranial axis. Figures in brackets are mean values of same dimensions in skulls of corresponding age)

GROUP	APPROX. AGE	NO. OF OBSERVATIONS	LINEAR DIMENSIONS (CM)									ANGLES					
			Basion-pituitary point			Basion-opisthion			Nasion-pituitary point			Foramino-basal			Spheno-ethmoidal		
			Mean	σ	S.E.M.	Mean	σ	S.E.M.	Mean	σ	S.E.M.	Mean	σ	S.E.M.	Mean	σ	S.E.M.
	years																
3	3–5	9	4.2	0.25	0.08	3.7	0.20	0.07	5.9	0.48	0.16	137.3	5.01	1.67	131.3	5.99	2.0
			(3.5)			(3.1)			(4.9)			(141)			(139)		
4	6–8	6	4.7	0.38	0.16	3.7	0.51	0.21	5.9	0.25	0.03	133.0	6.16	2.51	131.3	4.48	1.83
			(4.0)			(3.5)			(5.4)			(137)			(133)		
5	9–14	12	5.0	0.31	0.09	3.7	0.27	0.08	6.2	0.24	0.07	132.4	6.22	1.80	130.2	5.82	1.68
			(4.2)			(3.2)			(5.2)			(138)			(130)		
6	15–21	23	5.2	0.53	0.11	3.8	0.28	0.06	6.3	0.42	0.09	130.9	8.67	1.81	127.9	7.01	1.46
			(4.2)			(3.5)			(5.6)			(135)			(134)		
7	Adult	15	5.3	0.32	0.08	3.9	0.27	0.07	6.6	0.36	0.09	136.1	9.35	2.41	131.4	5.31	1.37
			(4.8)			(3.4)			(5.9)			(132)			(133)		

individuals radiographed, as calculated from measurements of the laminographic image corrected by a multiplication factor whose value is given by the distance between the x-ray tube and the plane of the object photographed, and the distance between the x-ray tube and the x-ray film. In the apparatus used to obtain the x-rays studied, the latter distance was constant at 76.2 cm. In practice, actual skull dimensions were determined by reading from a nomogram which had been specially prepared.

In considering the differences in absolute linear dimensions shown in table 1, it is necessary to remember that the mean dimensions of the x-ray series relate to individuals whose precise chronological age was known, whereas those for the skulls relate to groups whose ages were estimated from the state of their dentition. It is possible that each group of juvenile and adolescent skulls was slightly older than the ages given, since these were estimated from the times of dental eruption in British children of to-day; there is clear evidence that the permanent teeth appear somewhat earlier now than they did a generation or two ago (Clements, Davies-Thomas and Pickett, '53). It is also necessary to bear in mind the likelihood that there are racial differences between the two groups of observations summarized in table 1. The skeletal dimensions relate to a heterogeneous collection of skulls of which most, if not all, were European, whereas the x-ray data include a high proportion of Spanish Americans. Thirdly, it is necessary to note that in both cases we are comparing "mass means," and that these may obscure differences in dimensions or in trends of growth; alternatively, in the case of small samples, they may suggest differences where none in fact exist.

It is nevertheless noteworthy that, in general, corresponding linear dimensions determined from x-rays of living individuals are significantly greater than those measured directly on the skulls or from x-rays of the skulls. It seems unlikely that these discrepancies are due entirely to racial differences or to shrinkage of the skulls during drying. Since x-ray dimensions are always magnified, another probability is that the laminographic measurements, even though corrected, exaggerate the true dimensions.

At the same time, the x-ray figures confirm the direct measurements in so far as they show that there is a linear increase in the nasion-pituitary distance and in the basion-pituitary distance from the age of three until maturity. Statistical analysis shows that these changes are significant at a level of $P < 0.02$. The measurements of the foramino-basal and spheno-ethmoidal angles, whether measured with the pituitary point or the prosphenion as the point of inflection, do not, however, reveal any significant differences in the different age-groups. Contrary to the trend of the linear dimensions, the angular measurements made on the x-rays of the living subject were greater than those determined from the skulls.

The data are insufficient to show whether the post-pubertal changes in the dimensions of the cranio-facial axis which this study reveals are indicative of an adolescent spurt of growth. For the same reason, no significance can be attached to the fact that our observations failed to reveal any angular changes in the cranial base. A decisive answer to both these questions can be derived only from an analysis of successive observations on the same individuals, i.e. from a longitudinal as opposed to a cross-sectional survey. We have embarked on such a study, and hope that it may be continued long enough to provide information about both points. Correspondingly, the figures for the antero-posterior dimension of the foramen magnum in living subjects imply, as do those of the skulls, that there is little if any growth in this dimension after the 5th or 6th year.

SUMMARY

A cross-sectional analysis of laminographic x-rays of 6 individuals between the ages of two and one-half and 24 years of age shows that growth continues in the cranio-facial axis of the skull up to maturity. The investigation is being con-

tinued by means of repeated observations on the same individuals.

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AGE CHANGES IN THE BASICRANIAL AXIS OF THE HUMAN SKULL

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THREE FIGURES

INTRODUCTION

The basicranial axis is "a line drawn through the middle vertical plane of the *basioccipital, basiphenoid* and *presphenoid,* from the hinder extremity of the former bone to the anterior extremity of the last, at the upper end of the ethmo-presphenoid suture" (Huxley, 1867). The angle which this line makes with the plane of the foramen magnum (the mid-sagittal line joining the basion to the opisthion) is called the foramino-basal angle. It is nearly a right-angle in quadrupedal animals, but in man, in conformity with the different set of the skull on the vertebral column, it is much more open. The angle between the basicranial axis and a line continued from the anterior limit of the presphenoid (the prosphenion) to the nasion is called the spheno-ethmoidal angle (of the cranio-facial axis). It provides a crude measure of the disposition of the front part of the brain, in the purely descriptive sense that the angle becomes smaller the greater the relative volume of the frontal lobes, and the more the floor of the anterior cranial fossa is "pressed" down. The angle between the basicranial axis and a line joining the prosphenion to the alveolar point (prosthion) is the spheno-maxillary angle. It provides a measure of the extent to which the long axis of the facial skeleton is bent on that of the cranium.

According to Cameron ('24a, b) flexion of the facial on the cranial axis takes place not at the prosphenion (which in any event is difficult to locate precisely in mature skulls), but at the "pituitary point," which is defined as the anterior edge of the groove for the optic chiasma, just in front of the pituitary fossa. In most animals the angle subtended between and below the lines that join this point to the nasion and basion, and which Cameron called the "main angle of cranial flexion," is usually more than 180°, whereas in apes it is slightly, and in man well below this figure (Cameron, '25). Cameron also states that the angle, like the distance between the nasion and basion, is greater in negro than in white races (Cameron, '25, '26a), whereas the reverse holds for the distance between the nasion and the pituitary point (Cameron, '26b). The smallest "main angle of cranial flexion" occurs in the white races of mankind, and the angle progressively increases in size as the mammalian scale "descends" (Cameron, '27a).

Cameron ('27b) also noted that the angle varies with sex, but he does not appear to have studied the changes which it undergoes during growth. Age changes do, however, occur in the basicranial axis (as defined by Huxley). In the gorilla, according to Keith ('10), and according to Duckworth ('15) in Man as well as the great apes, growth of the brain in the posterior aspect of the skull opens out the foramino-basal angle, while a process of "correction," by which the plane of the foramen magnum is altered and the foramino-basal angle becomes smaller, sets in with the eruption of the permanent teeth and the growth of the masticatory muscles. This "correction" is explained (a) by growth of the basilar plate pushing the face forwards relative to the occipital condyles (or the condyles backwards relative to the face), and (b) by the displacement of the opisthion, or posterior point of the foramen magnum, as a result of the extension and upward growth of the nuchal area. A backward migration of the occipital condyles, and a consequent decrease in the foramino-basal angle, also takes place during a similar process of "correction" in the baboon (Zuckerman, '26). The term "migration" is, of course, purely relative, since the occipital condyles and the anterior margin of the foramen magnum, to which the anterior arch of the atlas and the odontoid process of the second cervical vertebra are anchored by ligaments, cannot alter their position on the vertebral column during growth. The joint between them is a reference point from which growth occurs in forward and backward directions, and the changes which take place in the plane of the foramen magnum are due to the displacement of the posterior margin (the opisthion) as a result of the remoulding of the planum nuchale of the occipital bone in response to the growth of the temporal and neck muscles.

Growth changes are not specifically described in the spheno-ethmoidal angle, but the indications from the values it assumes in different primates suggests that it is likely to be depressed after birth, and until the brain case ceases to enlarge. On the other hand, in the baboon (Zuckerman, '26) it would seem (although the observations on which this conclusion is based were few) that while the value of the angle is greatest at birth, and while it decreases during the period of the milk dentition, it increases again until in adult skulls it has practically assumed the same value it has at the start.

These views about the age changes which take place in the base of the simian skull are derived from limited data, and need to be re-checked. Furthermore, the belief that corresponding changes take place in the human basicranial axis and associated angles appears to be mainly derived from studies that relate to indices and angles different from those used by Huxley and Duckworth (e.g. Bolk, '09, '10). The present paper is a report of an enquiry that was designed to see whether the changes do, in fact, occur in man.

MATERIAL AND METHODS

Observations were made on a mixed collection of modern human skulls belonging to the Departments of Anatomy in the Universities of Birmingham and Cambridge. Ten immature skulls from the Department of Anatomy in the University of Manchester were also studied. No attempt was made to sex the specimens or to separate them into racial groups. It was recognized that not doing so carried the danger of increasing the variance of the observations, and therefore of obscuring age differences which might actually exist. Unfortunately, however, the number of immature skulls was too few to permit of much subdivision, and at the same time it was recognized that any effort to reveal growth changes by comparison of the mean measurements in different groups was, in any event, a method of analysis which, while unavoidable, was associated with theoretical shortcomings at least as great as those due to pooling of all the data (see p. 537).

Age-grouping of the data

Skulls were divided into the following arbitrary groups as defined by dental age:

	APPROX. AGE IN YEARS	NO.
Full-term and skulls with no milk teeth erupted	Under 1	8
Skulls with milk teeth erupting	1–2	12
Skulls with complete milk dentition	3–5	9
Skulls with only the first molars and permanent incisors erupted or erupting	6–8	28
Skulls with permanent teeth other than the third molars erupted or erupting	9–14	4
Skulls with all permanent teeth other than third molars erupted	15–21	20
Skulls with complete permanent dentition	Adult	99
Senile skulls, with loss of permanent teeth and absorption of alveolar margin	Senile	10

In any human population the times of eruption will be found to vary considerably, not only within a given period, but also from generation to generation (Clements, Davies-Thomas and Pickett, '53a, b). The figures relating chronological to dental age are derived from a recent survey of British children, and while they do not represent the full observed range for each stage of dental eruption shown, they should be sufficiently wide to account for all but very exceptional cases. Similarly, they should be wide enough to account for the ranges represented by the sample of skulls that was available for study, whether or not the mean times of eruption of the teeth in modern British children is different from whatever averages applied to the individuals whose skulls are now in the Departments of Anatomy of Birmingham and Cambridge.

Marking of the cardinal points of the basicranial axis and associated angles

Thistle-shaped lead slugs of the kind used in toy air-guns were glued to the skull as follows:

Opisthion: The slug was applied to the inferior surface of the occipital bone so that its anterior margin was flush with the posterior limit of the foramen magnum.

Basion: The slug was placed so that its posterior margin was flush with the endobasion.

Pituitary point and prosphenion: The slugs were applied by means of a specially designed forceps fitted with a mirror and electric bulb (fig. 1, A). The posterior margin of the slug was placed on the pituitary point, which was almost always definable. The prosphenion was more difficult to mark, since the spheno-ethmoidal suture may be obliterated posterior to the cribriform plate. The slug was placed with its center over the suture where this was visible. When it was obliterated, the slug was placed so that its center lay in the midline where the suture was judged to have been.

When the 4 slugs had been fixed, their position was recorded on a proforma (figure 2), which was then checked by a second observer by reference back to the skull.

X-raying of skull

The skull was fixed in a craniostat by means of three movable pointers, which operated in the same plane. The first pointer was applied to the nasion; the second on or about the lambda; and the third to the vertex (fig. 1, B). The

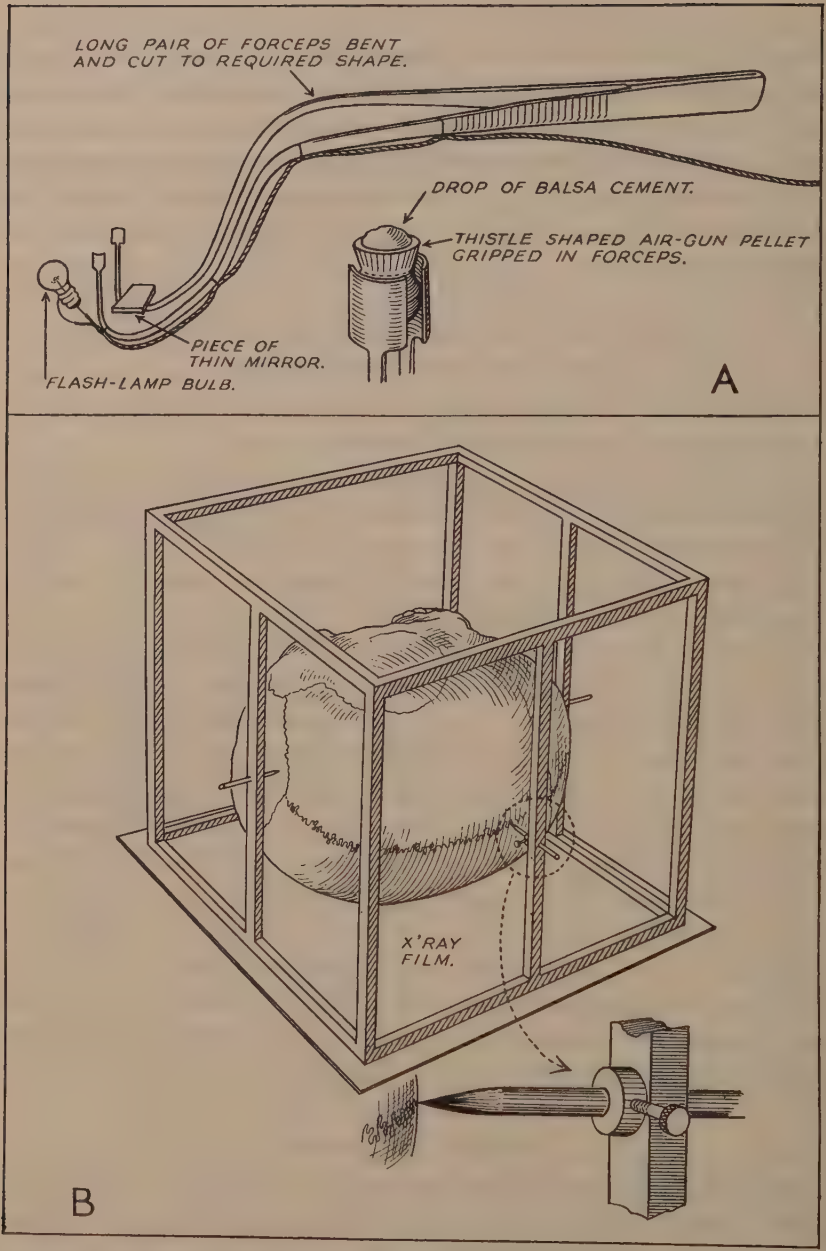

LONG PAIR OF FORCEPS BENT AND CUT TO REQUIRED SHAPE.
DROP OF BALSA CEMENT.
THISTLE SHAPED AIR-GUN PELLET GRIPPED IN FORCEPS.
PIECE OF THIN MIRROR.
FLASH-LAMP BULB.
A
X'RAY FILM.
B

Fig. 1 A. Forceps used to place slugs in anterior cranial fossa. B. Method of holding the skull while it was being x-rayed.

opisthion, basion, pituitary point, prosphenion and nasion were thus marked by 4 lead slugs and by the tip of the pointer at the nasion.

The frame containing the skull was then placed on its side on an x-ray film, the plane of the pointers being parallel to the film, and the distance between the two being kept constant. The tube distance was 40 inches from the film, the skull always being photographed lying on its right side.

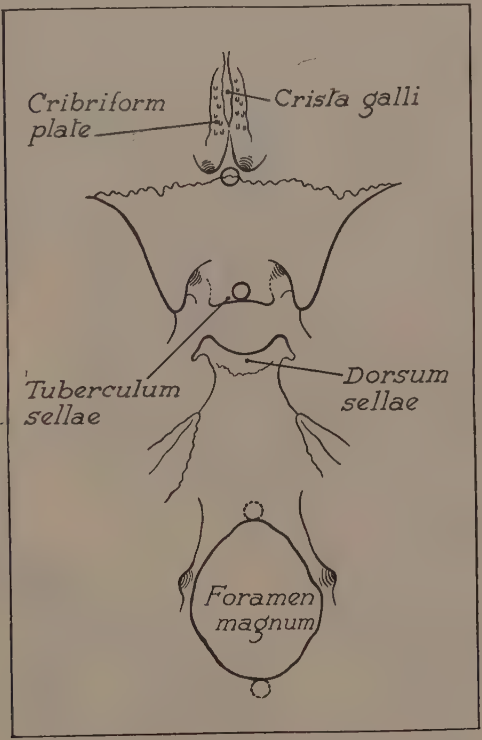
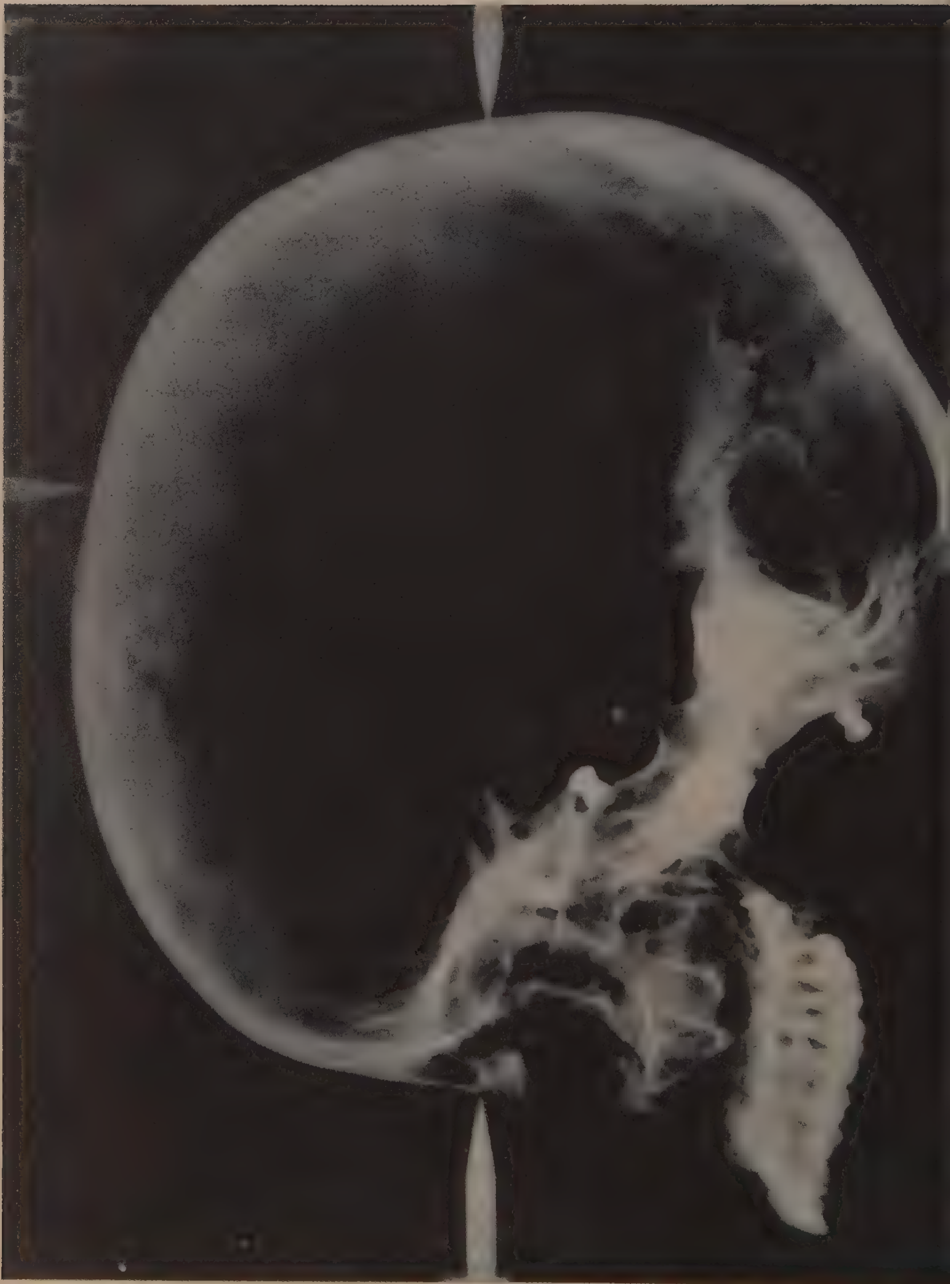


Fig. 2 Diagram of positions of slugs.

Measurement of x-ray films

The positions of the basion, opisthion, pituitary point, prosphenion and nasion were traced from each film (fig. 3) on to paper. The distance between the basion and opisthion, basion and pituitary point, basion and prosphenion, pituitary



point and nasion, prosphenion and nasion, were then measured on the tracings with steel dividers and a steel rule. The foramino-basal and spheno-ethmoidal angles were measured (a) in relation to the basion-prosphenion line as defined by Huxley, and (b) in relation to the basion-pituitary point line as defined by Cameron.

Relation of x-ray to skull measurements

The distances between the endobasion and opisthion, the opisthion and nasion, and the basion and nasion, were measured with steel dividers and calipers on each skull. These measurements were then compared with the corresponding dimensions of each x-ray film, and the ratio of the actual to the x-ray dimension calculated. In the whole series of 190 skulls (i.e. 570 observations) the ratio varied between 91.5 and 93.9%. In no single case did the three calculated ratios for any one skull differ from each other by more than 2%. The distribution of the differences between the three ratios for individual skulls was as follows:

	%
0 –0.5%	38
0.5–1.0%	38
1.0–1.5%	22
1.5–2.0%	2

Conversion of x-ray measurements to skull dimensions

The mean of the three ratios of x-ray to true distance was calculated for each skull. This mean ratio was then used to convert all the x-ray measurements for each specimen to actual skull measurements. Means and standard errors were then calculated for the latter.

Errors of measurement

After the whole series of skulls had been x-rayed, and the tracings measured, a series of 20 films was chosen at random, and new tracings made by a second observer. Three dimensions on each of the old and new tracings were then measured by both observers without reference to the previous data. There were thus 20 sets of 4 measurements for each of three dimensions. The maximum difference between any two of the 4 dimensions was expressed as a percentage of the mean of the 4 dimensions. The results were as follows:

DIAMETER	MIN. DIFF.	MAX. DIFF.	MEAN
	%	%	%
Nasion-basion	0.0	2.9	0.64
Nasion-opisthion	0.0	1.4	0.63
Basion-opisthion	0.0	3.3	1.93

Five months after the skulls were first examined, 20 were taken at random, and the nasion-basion, nasion-opisthion and basion-opisthion dimensions measured by a second observer. The two measurements varied as follows:

DIAMETER	MIN. DIFF.	MAX. DIFF.	MEAN
	%	%	%
Nasion-basion	0.0	3.1	0.89
Nasion-opisthion	0.0	2.0	0.85
Basion-opisthion	0.0	4.7	2.42

In both tests the relative differences between successive measurements were greatest in the case of the basion-opisthion diameter, which is what would be expected in view of the fact that it is the smallest dimension measured. The maximum discrepancy in the actual measurement of this diameter was in no case more than 0.1 mm.

The two checks thus indicate that the techniques followed can be relied upon to give reproducible and accurate measurements.

RESULTS

Table 1 relates to the measurements that were taken with the pituitary point as the anterior limit of the basicranial axis, and gives the means of the corrected values of the mid-sagittal linear dimensions of the base of the cranial cavity, and also the mean values of the foramino-basal and spheno-ethmoidal angles.

TABLE 1

Age changes in the base of the skull. (Pituitary point as anterior limb of basicranial axis.) (Figures in parentheses indicate standardized mean values with dimensions for group 1 taken as 100)

GROUP	APPROX. AGE	NO. OF SKULLS	LINEAR DIMENSIONS (CM)									ANGLES					
			Basion-pituitary point			Basion-opisthion			Pituitary point-nasion			Foramino-basal			Spheno-ethmoidal		
			Mean	σ	S.E.M.	Mean	σ	S.E.M.	Mean	σ	S.E.M.	Mean	σ	S.E.M.	Mean	σ	S.E.M.
1	*years* Under 1	8	2.8 (100)	0.32	0.11	2.1 (100)	0.06	0.02	4.0 (100)	0.31	0.11	130.0 (100)	13.06	4.61	143.1 (100)	8.31	2.94
2	1–2	12	3.3 (117)	0.52	0.15	3.1 (148)	0.39	0.11	4.5 (111)	0.37	0.11	137.8 (106)	8.69	2.51	140.1 (98)	4.72	1.36
3	3–5	9	3.5 (124)	0.25	0.08	3.1 (151)	0.33	0.11	4.9 (122)	0.39	0.13	141.2 (109)	6.00	2.00	138.9 (97)	6.53	2.18
4	6–8	28	4.0 (141)	0.28	0.05	3.5 (166)	0.29	0.06	5.4 (134)	0.41	0.08	136.9 (105)	6.16	1.16	133.2 (93)	4.38	0.83
5	9–14	4	4.2 (148)	0.19	0.10	3.2 (153)	0.25	0.13	5.2 (130)	0.36	0.18	135.8 (104)	1.71	0.85	129.9 (91)	3.43	1.71
6	15–21	20	4.2 (150)	0.36	0.08	3.5 (168)	0.28	0.06	5.6 (139)	0.30	0.07	135.2 (104)	7.36	1.65	133.7 (93)	5.22	1.17
7	Adult	99	4.8 (171)	0.33	0.03	3.4 (164)	0.30	0.03	5.9 (147)	0.31	0.03	132.3 (102)	6.47	0.65	132.8 (93)	6.35	0.64
8	Senile	10	4.8 (172)	0.42	0.13	3.5 (170)	0.24	0.08	6.0 (150)	0.25	0.08	134.0 (103)	6.04	1.91	135.6 (95)	5.21	1.65

The figures indicate that the base of the skull completes a little more than half of its antero-posterior growth during the first 8 years of life, and that the basioccipital, basisphenoid, presphenoid and ethmoid bones continue growing between puberty and maturity. The values of each dimension for the 8 age groups were subjected to an analysis of variance, and it was immediately apparent that significant differences existed within each set of data. A series of *t* tests was then made, group 5 being omitted because of its small size. It was found that at a significance level of $P < 0.02$ the basicranial axis (basion-pituitary point distance) in adult skulls is significantly longer than in skulls possessing only milk teeth. It is also significantly longer than in adolescent skulls in which all the permanent teeth except the third molars have erupted. A comparison of means shows that this dimension in fact increases almost as much after puberty as it does in the period which separates puberty from the time of eruption of the milk teeth. Corresponding results emerged from an analysis of the differences in the dimensions of the nasion-pituitary point distance. On the other hand, comparison showed that while the mid-sagittal dimension of the foramen magnum (basion-opisthion diameter) is significantly longer in adult than in juvenile skulls possessing only milk teeth, it is not significantly bigger than in skulls in which the permanent teeth are erupting, including the group corresponding to 6–8 years.

This analysis, therefore, suggests that the hinder part of the base of the skull ceases growing sooner than the central and anterior parts, which participate in the spurt of adolescent growth that affects the rest of the osseous system.

These linear growth changes are much more pronounced than those that occur in the foramino-basal and spheno-ethmoidal angles. If the value of the foramino-basal angle for the first year of life is taken as 100, the greatest value seen in any age-group is 108.6. It occurs in skulls in which only the milk teeth have erupted. The angle appears to become smaller as the permanent teeth erupt, and in adult skulls it is also of the order of 100. An analysis of variance indicated that there were significant differences in the angles in the different age-groups, and a series of t tests between pairs of observations identified these (at a level of $P < 0.02$) as existing between adult skulls and skulls in the 1–2 year, 3–5 year and 6–8 year age-groups respectively.

The size of the spheno-ethmoidal angle in general decreases with age, but here again the differences were less pronounced than those in the linear dimensions of the cranial base. Many of the differences were, however, significant at a level of $P < 0.02$ (e.g. age-groups 1–2 and 3–5 were significantly different from adult skulls, and also the 3–5 from the 6–8 age-group).

TABLE 2

Age changes in the foramino-basal and spheno-ethmoidal angles. (Prosphenion as anterior limb of basicranial axis). (Figures in parentheses indicate standardized mean values with dimensions for group 1 taken as 100.)

GROUP	APPROX. AGE	NO. OF SKULLS	FORAMINO-BASAL ANGLE			SPHENO-ETHMOIDAL ANGLE		
			Mean	σ	S.E.M.	Mean	σ	S.E.M.
	years							
1	Under 1	8	142.0 (100)	11.41	4.04	151.9 (100)	5.05	1.78
2	1–2	12	148.0 (104)	8.13	2.35	148.0 (97)	7.71	2.23
3	3–5	9	149.8 (106)	10.42	3.47	144.1 (95)	5.28	1.76
4	6–8	28	149.9 (106)	6.95	1.31	144.5 (95)	7.10	1.34
5	9–14	4	148.9 (105)	1.65	0.83	142.6 (94)	4.15	2.08
6	15–21	20	146.3 (103)	7.72	1.73	145.1 (96)	6.69	1.50
7	Adult	99	146.7 (103)	5.86	0.58	148.8 (98)	6.76	0.67
8	Senile	10	148.1 (104)	6.05	1.91	152.1 (100)	8.41	2.66

Table 2 gives the values of the foramino-basal and the spheno-ethmoidal angles when the prosphenion is taken as the point where the anterior limb of the cranial base bends during the process of growth. This series of measurements reveals no significant differences in the value of the foramino-basal angle in the different age-groups. The value of the spheno-ethmoidal angle in adult skulls is significantly smaller ($P < 0.02$) than in skulls of the under one year old group and in the 6–8 year old group.

DISCUSSION

This analysis has revealed the interesting fact that whereas the foramen magnum, i.e. the region constituting the hinder part of the cranial base, apparently ceases to grow in length after the milk teeth are shed, the middle and anterior segments of the base take part in a burst of growth in an antero-posterior direction during the period of adolescence. It also shows that significant changes take place during the course of development in the spheno-ethmoidal and foramino-basal angles. The fact that they occur in the former is implicit in the descriptions of the comparative anatomy of the cranial base given by Keith and Duckworth, but it does not appear to have been either described or established before. The growth changes in the foramino-basal angle do, however, conform to the pattern originally defined for the simian skull by Keith and Duckworth. The angle appears to increase between birth and the beginning of the eruption of the permanent teeth, and to decrease thereafter. This observation confirms that the same process of "correction" which occurs in the foramino-basal angle of the ape in consequence of growth in the planum nuchale, on the one hand, and the basisphenoid and basioccipital bones on the other, takes place in modern man. On the other hand, there is no indication in the present data that part of the explanation for the changes in the hinder end of the base of the skull is, as suggested by Keith ('10) "the absorption or atrophy" of the occipital squama behind the foramen magnum. This region of the skull appears to assume its definitive orientation to the vertebral column, and the foramen magnum its definitive size, soon after the permanent teeth have started to erupt.

So far as I know, the present findings stand on their own from the point of view of their quantitative expression. But the general conclusions to which they point are in line with Bolk's ('09, '10) observations on the position and slope of the foramen magnum in man and other Primates. Bolk, like one or two physical anthropologists before him, was critical of craniometric studies, directed at this problem, which used a base-line that passed through the base of the skull, his main argument being that it is wrong to define the position of the foramen magnum in relation to the long axis of the skull by reference to an angle whose value is determined not only by the position of the foramen magnum, but also by such factors as the inclination of its plane and the degree of bending of the cranial base. This criticism may well apply to studies in which the position of the foramen magnum is expressed in this way, but it obviously has no force when one is considering, as did Duckworth, the bending of the anterior and posterior base of the skull on the basicranial axis, or when the basion is treated as a fixed anatomical point at which the skull is at all times anchored to a fixed point on the vertebral column.

The basal index which Bolk used expressed the ratio of the preoccipital part of the cranial base to the whole base. This he defined as a line joining "the lowest part of the frontal wall of the skull where the inferior surface of the skull bends inwardly in a more or less sharp curve to be continued in the roof of the nasal cavity" to the point on the midline of the posterior wall of the cranial cavity which was "at the greatest distance from its anterior point," which he designated the Fronton. This line was divided into preoccipital and postoccipital parts by projecting to it a perpendicular from the basion. Although the construction of an index in which the two variables are highly correlated is open to certain criticisms, it is obvious that, in general, its numerical value would become larger the more posterior the position of the basion.

In the first of his two papers on the subject, Bolk ('09) discusses the value of the index in a series of 20 fetal human skulls, 54 human skulls between 1 and 12 years of age, and 60 adult human skulls; and in 42 New World monkeys, 29 Old World monkeys, 17 gibbons, 13 orang-utans, 4 chimpanzees and 10 gorillas. Most of the sub-human primate skulls were of mature animals. All the specimens had been cut in two along the median plane, and the measurements were made on pantographic tracings.

The average value of the index in the sub-human primate forms varied between 57 and 86. The highest, 86, occurred in Howler monkeys *(Mycetes)*, and the lowest, 57, in an unspecified species of cercopitheque monkey. The average values of the index in the chimpanzee, gorilla and orang-utan were respectively 64, 61, 61. In man, on the other hand, the value of the index varied between 52 and 40, the average being between 45 and 50. These figures illustrate very forcibly the fact that the foramen magnum is more anteriorly disposed in man than in the great apes. Further comparison also showed that in man, as well as in the anthropoid apes, the index becomes greater with age, i.e. the position of the basion becomes more posterior relative to the cranial base as growth proceeds.

In his second paper, Bolk ('10) showed that the value of the index is correlated with the slope of the foramen magnum: that is to say, the more posterior the foramen, the more vertical it becomes. The measurement used by Bolk to demonstrate this generalization was the value of the angle between the vertical line projecting from the basion to his base-line, and a line connecting the basion and opisthion. In 8 adult gorillas the angle varied between 63° and 80°, and in 8 orang-utans between 58° and 80°. The highest value in any sub-human Primate was 84° (a female macaque). The average angle for full-grown human skulls was, on the other hand, about 100°. Bolk also found that the angle became smaller with age, both in apes and human beings — that is to say, that the younger the ape the more horizontally disposed the foramen, and the younger the human being the more the plane of the foramen faces downwards and forwards. Bolk does not refer to a process of correction of the kind defined by Keith and Duckworth, but it is worth noting that of 55 values he gives for the angle of the foramen magnum in children's skulls, the three highest values (114, 114, 113) occurred in skulls aged 4 to 6 years. Leche's ('12) studies of monkey skulls (in particular Howler monkeys) in which he used a base-line that followed the lower surface of the hard palate, also led to corresponding conclusions about the age-changes that occur in the position and slope of the foramen magnum.

While there can be no doubt about the trend of the growth changes that take place in the base of the skull, it does not follow that either their occurrence in time, or their magnitude, is accurately represented by the results of the analysis reported in the present paper. The difficulty is that while a comparison of average measurements for groups of human beings of different dental age is adequate to show the size distribution of the dimensions studied at different stages of growth, the method is bound to obscure the growth changes that occur in any single individual. These are likely to be episodic rather than continuous. Corresponding phases of growth in the basicranial axis would not necessarily occur at the same stage of dental eruption in different individuals, particularly during the period of adolescent growth, and a comparison of averages would, therefore, give a damped-down picture of the phases of growth that actually occur. There are two other reasons why the present analysis may give too conservative a picture of the growth changes which take place in the base of the skull. The first is that the classification of skulls by dental age may result in units of time which are too wide; and the second, which has already been indicated, is that the variance of the observations may have been increased because it was necessary to pool both male and female skulls. The results of the x-ray enquiry reported in the following note (Grossman and Zuckerman, '55) encourage one to believe that it might be possible to investigate the problem of the detailed growth changes in the cranial base by means of a longitudinal survey of given individuals.

SUMMARY

1 A radiographic analysis was made of the basicranial axis and associated angles in 190 European skulls of mixed origin, and ranging in age from the first year of life to old age. The cardinal points of the axis were marked by means of lead slugs introduced into the cranial cavity.

2. A comparison of the means for different age groups showed that the base of the skull completes somewhat more than half of its antero-posterior growth during the first 8 years or so of life, and that the basiooccipital, basisphenoid, presphenoid and ethmoid bones take part in a burst of growth in an antero-posterior direction during adolescence.

3. The basio-opisthion diameter, i.e. the hinder part of the cranial base, ceases to grow after the milk teeth are shed, and after the permanent teeth start erupting.

4. The foramino-basal angle is smallest at birth, increases during the period the basion-opisthion diameter is increasing, and then decreases again.

5. The spheno-ethmoidal angle decreases throughout the period of growth.

ACKNOWLEDGMENTS

I am much indebted to Professor J. Dixon Boyd of the Department of Anatomy, Cambridge University, and to Professor G. A. G. Mitchell of the Anatomy Department of Manchester University, for their kindness in allowing me to study the skulls in their collections. I also wish to express my gratitude to Miss J. F. Miller and Mr. W. J. Pardoe for their technical help during the course of the study.

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BRIEF COMMUNICATION

A RARE CASE OF CANINE VARIATION

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Numerical variation of the teeth, which is common in all animals including man, is very rare in regard to the canine. F. Colyer, who has written the most exhaustive study on this subject ("Variations and Diseases of the Teeth of Animals," London, '36) deals also with the dental variation among the primates. But he does not find a single supernumerary canine in 675 gorilla skulls (546 with mandible), 560 chimpanzee skulls (467 with mandible), 85 Symphalangus skulls with mandibles, 5,900 specimens of 15 different genera of the Cercopithecidae, 2,199 specimens belonging to 10 different genera of the Cebidae, 247 specimens of the Hapalidae, and 775 specimens belonging to different subfamilies and genera of the Lemuridae (pp. 2, 26, 52 f., 61–63).

In a sample of 267 orang skulls (229 with mandibles) and 28 isolated mandibles, Colyer noticed two mandibles with an extra canine. One of these cases, previously described by Hrdlicka (Proc. United States Museum, '31) refers to a supernumerary tooth in the region of the left canine in the mandible. The extra tooth located on the inner side of the arch, is larger than an incisor, but the root is flattened similar to that of an incisor. The canine has been lost from the specimen. Hrdlicka provided the following measurements: First incisor 9.2 mm by 6 mm; Second incisor 10.3 mm by 5 mm. The extra tooth 11.6 mm by 7.5 mm. Colyer has regarded this tooth as a canine (p. 17, fig. 20). In another specimen (Colyer, p. 17 f., fig. 21) "there are two deciduous canines in the left side of the mandible, the teeth are not exactly similar in shape; the one adjacent to the second incisor, although distinctly a canine, shows in a slight degree certain characteristics of a second incisor. In this specimen there are two developing permanent canines, the teeth being unequal in size.'' Finally, in a sample of 306 Hylobates skulls with mandibles, Colyer found one single case of Hylobates hoolock with duplicate deciduous canines on the right side of the maxillary, both of which were rotated (p. 21, fig. 24).

This shows how extremely rare duplicate canines are in primates. For in 11,014 skulls and a great number of mandibles, only three cases of duplicate canines were observed by Colyer. In two cases out of these three, the duplicate canines are incisiform, mandibular, and deciduous, and in one case the lower duplicate permanent canines had not yet erupted. The only case of a supernumerary canine in a gorilla of which I know is that in the upper left maxillary described by E. Selenka (''Menschenaffen, Anthropomorphae,'' *1*, chapter 2, Wiesbaden, 1898–1900, 141, fig. 172) which, though having the typical form of a canine, is however smaller than the normal canine and located inside of it.

How extremely rare supernumerary canines are in humans, follows from the fact that out of a sample of 48,550 adult persons subjected to an x-ray test, Stafne (in H. König: ''Kritischer Beitrag zur Entstehung der Zahnanomalien der Form und der Zahl. Zahnaerztliche Rundschau, '39, H. 24, 1009) found only two cases in the upper and one in the lower maxillary. L. Verdiani (Anomalie dentarie. Riv. ital. Stomat., '38, no. 8, 437) has described two cases, and De Jonge-Cohen (Verdoppelung des Eckzahnes. Paradentium, *12*, '40, H. 11/12, 158) one case of supernumerary canines in human beings (quoted by P. Kluge: Ueber Vorkommen und Frequenz ueberzaehliger Zaehne bei den anthropoiden Affen mit besonderer Beruecksichtigung der ''Distomolaren'' im Sinne Bolks. Wissensch. Ztschr. d. Univ. Greifswald, *3*, '53–'54, 533–556).

In view of this extreme rarity of canine duplication, I should like to put on record the case of a Hylobates hoolock skull (with mandible) in the American Museum of Natural History (no. 112694) with two fully developed upper left permanent canines (fig. 1). An x-ray picture (fig. 2) shows that there is practically no difference in the length of the roots of the two teeth. The general degree of wear is similar in both teeth, so that they might have erupted more or less at the same time. Only in the area where the more median upper canine has been in contact with the lower canine does it show a greater degree of wear, whereas the more lateral canine was in contact with the lower canine only at its lower point. Because of the presence of

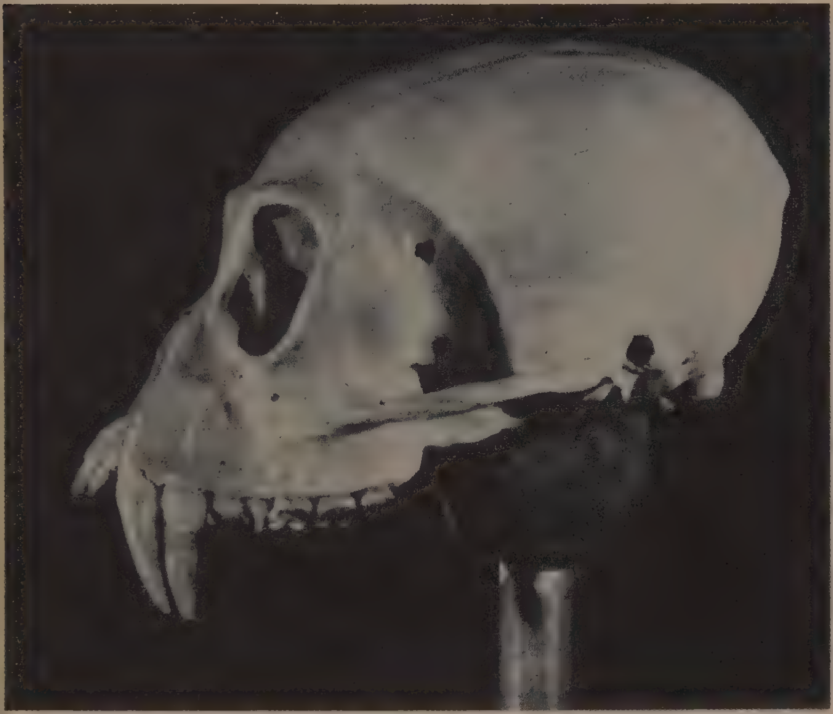
Figure 1

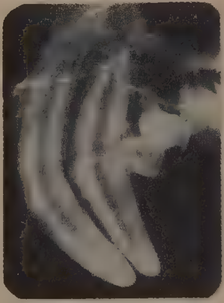
Figure 2

the two canines, the first left upper premolar is slightly crowded. Otherwise, the occlusion and numerical situation are normal in the upper and lowed jaw.

The importance of supernumerary canines lies in the fact that they clearly disprove the atavistic theory, for two canines never occurred at any stage of mammalian dental evolution. It is for this reason that the occurrence of supernumerary canines has been so stubbornly denied by some of the representatives of the atavistic theory.

REVIEWS

THE FOSSIL EVIDENCE FOR HUMAN EVOLUTION. An introduction to the study of paleoanthropology. W. E. Le Gros Clark. 181 pp. University of Chicago Press, Chicago. 1955. $6.00.

In the first chapter of this compact little book Clark has outlined the theoretical, methodological, and practical problems confronting the student of human evolution. In the first 50 pages the need for a generally accepted terminology is forcefully presented and a classification of the Hominidae is offered. The classification is supported by using the ''concept of total morphological pattern'' to replace the difficulties which arise from conclusions based on the comparison of isolated characters, complex measurements, and faulty statistics. The appeal is made to understand the anatomy of the fossils first, then to use accurate geological dates and modern evolutionary theory in their interpretation. Clark attributes much of the present confusion about human evolution to the misuse of taxonomy, the multiplication of undefined new terms, and the use of colloquial names. The difficulties and fallacies of the biometric approach are skillfully outlined (p. 22–37), and the necessity for morphological equivalence and biological understanding of things measured is decisively presented. This brief outline of Clark's point of view and the reasons behind it will be of interest and value to the beginner and professional alike. The first chapter should be read both before and after the chapters dealing with the fossils, because the general points become much clearer when applied to particular cases.

The remaining 4 chapters consider the genera *Homo, Pithecanthropus, Australopithecus,* and the origin of the Hominidae. A formal anatomical definition is given for each of the genera, and their characteristics, inter-relations, and age considered. Starting with *Homo sapiens* and working backward to the less well-known forms is an effective method of presentation. The genus *Homo* is divided into two species, *sapiens* and *neanderthalensis. Homo neanderthalensis* is restricted to mean the late, Western European (classic) Neanderthals only. Steinheim, Ehringsdorf, Mt. Carmel, Swanscombe, and Fontéchevade are classed as *Homo sapiens.* The Krapina, Solo, and Rhodesian skeletons are included in the genus *Homo,* but of uncertain specific position. *Pithecanthropus,* including Java man and Pekin man, is regarded as earlier in time and more primitive morphologically than *Homo, Australopithecus* is considered as of Villafranchian age and to approach the apes still more closely than *Pithecanthropus.* The Hominidae are thought to have sprung from a Miocene, or early Pliocene, ape. Clark has been successful in presenting a considerable amount of morphological information on a large number of fossils. He continuously emphasizes the importance of geological dating, range of variation, and the adequacy of the fossil record. Differing interpretations are often indicated, but not emphasized. Questions of reversibility, parallelism, and evolutionary trends are discussed in numerous places. The illustrations are poor in quality and few in number, and it is to be hoped that this fault will be corrected in the next edition of this excellent book. It is too bad that a student using the best introduction to the study of fossil man must seek illustrations elsewhere.

The ''Fossil Evidence for Human Evolution'' is an extremely useful book. Of course, authorities will differ on such points as the time of origin of the Hominidae, whether Java man should be in a separate genus from *Homo,* or whether the distinction of Neanderthal man is more than racial. Such items as the number of genera of the australopithecines will be clarified in time, but there are some deeper problems which might receive the reader's attention. I believe that there are several very different points of view on human evolution which can be defended and that it is a mistake not to indicate the real differences and give the names of the opposition. On page 9, Clark urges ''that this simple and now *generally accepted* scheme of classification of the Hominoidea should be adhered to''. . . (italics mine). The scheme is reasonable, but it is not generally accepted. Other points of view (for example those of Dobzhansky, Mayr, Straus, and Zuckerman) do not fit this particular terminology. While agreeing entirely with Clark that there has been an undesirable multiplication of ''fancy terms,'' it is necessary to emphasize that some of the terminological differences stand for different conceptions of primate evolution, and that, as long as there are several reasonable ways of arranging the fossils, different terminologies will be necessary. In short, there is no possibility of agreeing on terms unless there is basic agreement on the grouping of the fossils. The multiplication of synonyms and special names sholuld be avoided, but progress beyond that depends on clarification of human evolution, not agreement on terminology. In his desire to escape statistical fallacies, Clark uses almost no measurements at all. This leads to an over-emphasis of the differences in cranial capacity between the early, generalized Neanderthals and the later representatives. It also leads to repeating the old error that the arms of the apes are much longer than those of *Homo sapiens,* when the range of arm to trunk in modern man overlaps that of both chimpanzee and gorilla. Far from there having been a trend toward increasing arm length common to all the Pongidae, the arms of the gorilla have probably undergone a secondary reduction quite comparable to that of man. In evaluating the differences between fossils (for example, *Telanthropus,* p. 158), Clark speaks of the range of variation, and such ranges need to be expressed metrically. Clark uses measurements in his technical papers, and, because at the moment abuse may seem more prevalent than use, the difficulties of biometry should not lead people to lose sight of its utility.

The concept of total morphological pattern is not altogether clear to me, and seems to be used in two rather different senses. For example, in the apes, the pattern of the interlocking upper and lower canines, first lower premolar, and the diastema is a pattern whose parts are functionally related. But the characteristics which differentiate classic Neanderthal man from the earlier forms seem to be a series of functionally unrelated traits which, perhaps for many different reasons, are common in the same population. The identification of functional complexes seems entirely different from stating that certain anatomical features are found close together in a particular animal, say in the mastoid region of *Homo sapiens.* Since the concept of pattern is central to Clark's theories and is certainly useful, I hope that he may expand it more fully in the pages of this journal.

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HYPEROSTOSIS CRANII. By Sherwood Moore. xxii + 213 pp., 106 Illus. Charles C Thomas, Publisher, Springfield, Illinois. 1955.

Released by courtesy of the Barnes Hospital, under the auspices of the Frank Phillips Foundation, Inc., the author has presented an extensive array of references of the past 130 years since Morgagni first described this relatively rare disorder at Padua, 1765. These 315 published articles and monographs seem to cover the condition without stint, to which is added the three hundredth and sixteenth and by all counts the best.

Frontal intracranial osteophytes have too often, according to the author, been considered "benign" and the symptom complex denied.

In this regard the osteophyte is but one of the changes observed and should be considered only a phase or stage of the abnormality. Intracranial contents, as it seems, are able to accommodate to space encroachment in a most unusual manner. To this extent only, may the hyperostosis cranii be considered ''benign.'' The disorder is not fatal; life is not shortened and the skull changes, accompanied by obesity and male facial hirsutism in women, are the only autopsy findings. The author considers the last two are often missing in the syndrome. This arrangement of disturbances takes the form of a relatively consistent though many sided pattern. Even an x-ray demonstration of the hyperostosis is not essential to a diagnosis. Many types and stages are reported by the author, beautifully illustrated by unusual and properly selected roentgenograms. Anyone who has ever tried to collect a series of skull films well knows the trials of the writer.

The hyperostoses are classified into four types, and considered as stages, rather clearly drawn, in the development of the process. Each probably progresses into the next, with an increase of the midsaggital thickness from 12 mm to 20 mm over a 12 year period. Some crania did even better, exceeding 21 mm in thickness over a 9 year span.

Development and the form of hyperostosis of the skull arises from and is governed by its contents and investments, the pericranium and the outer layer of the dura mater and the circulation of both. Both the compact bone of the inner and much less the outer tables and the canellous bone of the diploe are affected, the latter far more than the former. Indeed the tables play a relatively passive role in the formation of the hyperostosis.

There are certain proponents of the theory that retreat of the cerebrum away from the inner table brings about hypertrophy of the frontal bone through negative intracranial pressure. This theory is of two orders. Gravity pull exerted on the bone, through long continued dorsal decubitus in the old and infirm, combined with the pull of those fibers of the dura which are strongly attached to the bone, producing the rugose surface of the involved area, and the other is that it is due to brain atrophy. The first of these theories proposed by Morel and Grieg is untenable for reasons which need not be further considered. The second theory, strongly advocated by Henschen, is that atrophy of the brain reduces its volume with resulting bone hypertrophy ''ex vacuo.'' It is hard to reconcile the regional symmetry and irregular surface of the bone in H.F.I. with brain atrophy as effect and cause. Conceding that brain atrophy in females is of the frequency given by Henschen it does not explain the absence of hyperostosis in many cases of brain atrophy in women. The occurrence of hyperostosis in men, which is rare, is not sustained by the theory. It could however explain the cause of hyperostosis which, is not regional but is diffuse.

The author adds: The mineral metabolism of dairy cows and that of the male deer, if studied and known, might throw light on that of the human. If so, a clearer understanding of the relationship, if any, of mineral metabolism in the production of calvarial hyperostosis, might be discovered. There is strong evidence that diffuse hyperostosis of the skull and skeleton could be produced by the administration of hormones on animals of the opposite sex, as it undoubtedly has in the cases one woman and one man, given by the author.

Treatment is well handled. Headache, often unremitting and disabling is treated in many ways. Cranial decompression, tying off of the middle meningeal artery and the use of analgesics, are discussed. Muscle weakness and fatigue are reported as favorably controlled by glycine therapy. Convulsions may need the usual care.

Method of investigation consist of an analysis of hospital records, including thousands of x-ray plates, a detailed anthropomorphic study of the skull, including 1,198 from the Robert J. Terry Anatomical Museum, under the ever helpful eyes of Professor Terry himself and his remarkable successor, Dr. Mildred Trotter, presently the President of the AAPA. Hence this monograph, a re-doing of an old subject is quite unique.

A chapter on the paleopathology of the disorder adds stature to this remarkable study. Mound builder's skulls, 162 in number from the St. Louis area, failed to show the disease. No examples were found in the collection of the National Museum in Washington, D. C., the American Museum of National History or the Chicago Museum of Natural History. Pithecanthropus erectus and the Mayan Indian probably demonstrate the condition. The "Venus of Willendorf," an Aurignacian figurine, may indicate the obesity so characteristic of the female affected. Other prehistoric works of man, particularly surface carvings, many picture similarly obese females from long ago. Who knows? The idea is quite plausible.

The author speculates that human deterioration, and even disappearance of groups of people, may have arisen from failure of the endocrine system. Perhaps the hyperostotic cranii syndrome is one such objective agent.

In the reviewer's opinion, there is very little to offer of a critical nature about this interesting report on a rare syndrome. The average reader, medical anthropological or anatomical, may feel overworked by the minute details and exhaustive analyses presented. However, this is a trite criticism of a well developed monograph that will stand as the most up-to-date reporting of an obtuse disorder. This reviewer liked every word of it.

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BONE, AN INTRODUCTION TO THE PHYSIOLOGY OF SKELETAL TISSUE.

By Franklin C. McLean and Marshall R. Urist. xii + 177 pp.; 26 illustrations. The University of Chicago Press, Chicago. 1955.

This book is from the Scientist's Library of Biology and Medicine. In the preface Peter P. H. DeBruyn recommends the monograph as authoritative information of interest and value to teachers, investigators and students of biology and medicine. Rather broad coverage, but actually this small, almost pocket size compendium, contains the concentrated information of a life time of investigations in calcium metabolism and bone. Both the biochemical and the morphological viewpoints are clearly and easily stated.

There are chapters directed toward explaining bone as a tissue of many varities with detailed presentation of the histogenesis, including the types and activities of cells, not omitting the illusive "osteoblast," and the origin of bone. Structure and chemical composition are well defined. An illustration of the crystaline character of bone salts is very revealing. All phases of bone dynamics are discussed, including enzyme action during deposition and resorption. These two phases take on clearer meaning because of the author's explanations.

A chapter is devoted to mineral metabolism, a subject close to the life time work of the senior author, and another to radiation, isotopes and bone. Healing of fractures, condensed within twelve of the most informative pages, is a chapter alone worth the price of the monograph. A good deal of water must still push over the dam before the last word is said relative to fracture healing, but here is an understandable explanation that will satisfy most everyone until more penetrating methods of study are available. As a teaching chapter, it is especially clear and concise and might be learned verbatim by candidates for orthopedic examining boards. Concerning bone grafts they state, homogenous and autogenous bone appear to be equally effective in most cases of inlay, onlay and intramedullary grafts. All are capable of producing union in the majority of cases. Such advice is particularly pertinent.

The pathological physiology of bone is ably and concisely discussed, with nothing new added. The bibliography is divided into chapters and placed at the end of the text. This is an inconvenience.

The format is attractive, line drawings are well done and the material reads smoothly. There is a great deal to recommend this book, especially to students of medicine, residents in the specialties, orthopedic surgeons and many others concerned with bone. A physical anthropologist in particular will find much of value relative to the bone material with which he works. Nothing could be more authoritative until others, from a life time of study, put down their conclusions in as readable a form.

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BOOK NOTES

COLD INJURY. By M. Irene Ferrer, Ed. Transactions of the Third Conference February 22, 23, 24 and 25, 1954. Fort Churchill, Manitoba, Canada. Pp. 226. $4.50. Josiah Macy, Jr. Foundation, New York. 1955.

The anthropologist interested in the interaction of man and his climate will find many new and fascinating facts in the transactions of the third Macy conference on cold injury. Particularly noteworthy is a paper by G. Malcolm Brown entitled, ''Metabolic Studies of the Eskimo.'' This study might be better called the Physiology of the Eskimo. His work showed many differences between the physiology and biochemistry of Eskimos and American Whites. Some of these differences appear referable to nutritional factors but others remain unexplained. Of almost equal interest is ''A Comparative Study of Young Eskimo and Indian Males with Acclimatized White Males'' by M. F. Coffey. The comparison refers to tests of manual dexterity performed in the arctic cold. Eskimo and Indian performance was very superior. Dr. LeBlanc's paper presents several important facts concerning the insulating qualities of human subcutaneous fat. Other reports in the book deal with rat experiments. While the results of these studies are very suggestive, their applicability to man should be viewed with reservation.

One particularly valuable article makes it worth while mentioning the Second Macy Conference on Cold Injury. Since World War II members of the Surgeon General's department have felt that there was probably a biologically determined racial difference in frost bite susceptibility. Leonard Schuman's paper, ''Epidemiology of Cold Injury in Man,'' in the transactions of the second conference reports on a carefully executed study done during the Korean War. Schuman concluded that frost bite was much more common among American Negroes than among American Whites, even when factors of exposure, personal hygiene, and state of birth were controlled.

Each paper in these books is followed by a panel discussion by physiologists involved in similar studies. The reader will find this discussion feature very helpful in that it allows for careful evaluation of the studies without a detailed knowledge of physiology.

PAUL T. BAKER

DU CRANE ANIMAL AU CRANE HUMAIN. By A. Delattre with a preface by H.-V. Vallois. Pp. 104. Masson et Cie, Paris. 1951.

The author believes that his method of comparing crania of man and other mammals gives the key to the transformations that have taken place in the course of evolution. He studied the profiles of skulls oriented in the plane of the two horizontal semicircular canals and found the line between them to be the crucial axis in the rearrangement of the different parts of the skull caused by the upright posture. All other methods of orientation are believed to be misleading, but he comes to many conclusions that are quite similar to those to be found in other works of this nature. The study is purely craniological, unsupported by experimental evidence. All the references are in French.

NEIL C. TAPPEN

THE PHYSICAL TYPE OF THE PAA-KO POPULATION. By Spencer L. Rogers. Part VI of ''Paa-ko, Archaeological Chronicle of an Indian Village in North Central New Mexico.'' (Monograph 19, Part VI, The School of American Research.) 48 pp., 42 tables, 13 line-drawings, 53 plates. Santa Fe, New Mexico.

In reporting on the 28 skulls and associated skeletal parts from Paa-ko pueblo, Rogers has taken on a task made uninviting on two counts: The adult series are small — 17 males and 6 females — and may not be properly representative of the Paa-ko population; and most of the skulls have cradleboard flattening. Considering these handicaps, he has done a thorough and workmanlike job in fitting the Paa-ko skeletal material into the known picture of Southwestern racial history.

In his analysis, Rogers compare his larger pre-Columbian series with a small post-contact series, and although there are metric differences between them they are wisely discounted because of inadequacy of sample. In his handling of the cradleboard flattening, Rogers has gone beyond the usual methods by designating the occipital type as having an angle of 80° or more with the eye-ear plane, and the lambdoid type as having an angle of below 80°. The lambdoid type is the prevalent kind of deformation at Paa-ko. In addition the asymmetrical character of the deformation is expressed in terms of angulation from the mid-sagittal plane, with the finding that while asymmetry is the rule, there is no preference as to side. Finally figures are presented showing that the angulation of the basilar part of the occipital bone relative to the eye-ear plane decreases with severity of deformation.

Comparison with Pecos pueblo, using deformed skulls, shows high metric similarity between the two series. Using Hooton's morphological types, it is apparent that Paa-ko lacks the ''Plains Indian'' and ''Long Faced European'' components that are in the later strata at Pecos. In reconstructed stature, 19 Paa-ko males average 158.7 cm, low even for Southwestern Indians.

Arthritic changes in the vertebrae occurred in 83% of the Paa-ko series — a very high figure possibly reflecting a considerable mean age. This cannot be checked since Rogers gives no breakdown by age. Considerable tooth wear occurred, the most frequent being 3rd degree (extensive exposure of dentine). Caries are nearly half the frequency found at Pecos, and are found in 24% of the Paa-ko skulls.

In conclusion, Roger's paper with its summary tables and photographs of each skull, is a welcome addition to our knowledge of Southwestern skeletal material, and represents a major effort to make our traditional craniologic techniques tell a meaningful story.

MARSHALL T. NEWMAN

THE ABORIGINAL POPULATION OF THE SAN JOAQUIN VALLEY, CALIFORNIA. By S. F. Cook. (Anthropological Records, 16:2). Pp. iii + 78. University of California Press, Berkeley and Los Angeles. 1955.

Using many historical records and ethnographic reports, the author has reconstructed the most probable population counts for two periods in the history of the aboriginal peoples of the San Joaquin Valley. At the time of the first intense White contact, around 1800, Cook estimates the number to be 83,820. By 1850 it was 19,000, more than a four fold decrease. Estimates are made for each sub-group of the total population. Cook's carefully prepared estimates are a welcome addition to our far too sparse knowledge of aboriginal demography, but most importantly, can serve as a model for other workers. Our understanding of human population genetics and evolution requires knowledge of population sizes.

FPT

NATIONAL SCIENCE FOUNDATION RESEARCH SUPPORT

Research proposals directed to the Division of Biological and Medical Sciences of the National Science Foundation will be received at any time. The proposals on research projects to begin in June or September 1956, will be reviewed during March. These proposals should be received by the Foundation prior to February 1, 1956.

Projects in the areas of anthropology, human ecology, functional archaeology, experimental social psychology, and demography are included in the Division's program.

SOME HISTOCHEMICAL PROPERTIES OF THE ORGANIC SUBSTANCE IN NEANDERTALIAN BONE

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SEVEN FIGURES

For more than a century there have been reported in the literature, chemical and histological studies which prove the presence of organic substance in fossil bone. (See literature cited: Schaffer, 1889; Rogers, '24; Aron and Gralka, '25; and Michaëlis, '30.)

Recently, Cook and Heizer ('47) have emphasized the importance of quantitative nitrogen determination in fossil remains as a fundamental and reliable procedure to estimate their chronology. Organic matter in human fossil bone has been histologically demonstrated in skeletal material belonging to prehistoric age. Baud and Morgenthaler ('52), employing the electron microscope were able to show the existence of perfectly preserved collagen fibers in a Magdalenian skeleton.

The present paper reports the results of a preliminary investigation on the histological and histochemical properties of the organic substance (ossein or organic bone matrix) in the Neandertalian mandible named "Circeo II" (see Sergi, '39 and '43). These features have been compared with those of the organic substance obtained from other fossil bones.

DESCRIPTION OF THE MATERIAL

The small fragment of bone submitted to the present investigation came from a tiny splinter which had detached itself from near the inferior border of the external left side

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of the mandible "Circeo II" (mandible A) in correspondence to a frontal plane passing through the interalveolar septum between the canine and the first premolar (see fig. 1).

The specimen and the following description of the mandible was kindly furnished by Professor S. Sergi whose complete study of it has been published (Sergi, '54, '55).

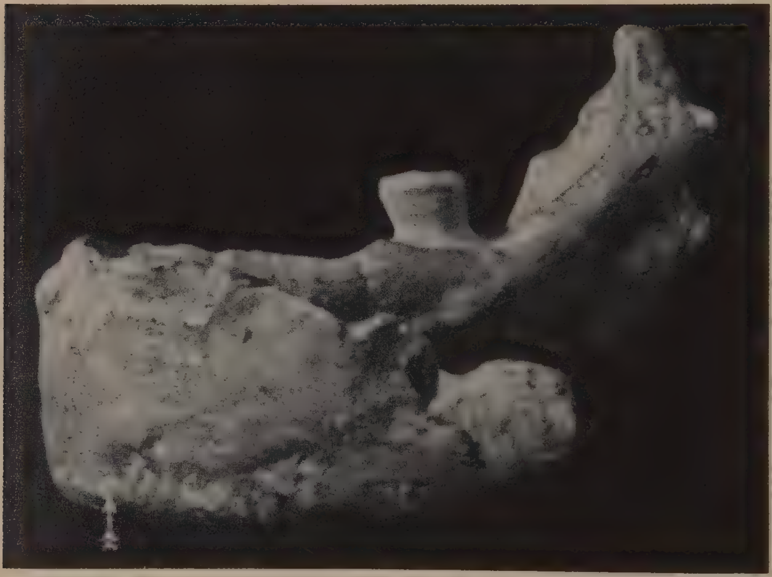


Fig. 1 Mandible "Circeo II." The arrow shows the seat from where the small investigated fragment has fallen. (Photograph by courtesy of Prof. S. Sergi.)

> "The mandible was found in the Guattari grot in 1939, at the time when the Neandertalian skull "Circeo I" was being discovered. As to chronology it is ascribed to Epiwürm II (A. C. Blanc), and as to morphology it belongs to the *Homo neandertalensis* (S. Sergi). (See: Catalogue des Hommes fossiles, edité au nom de la Commision pour l'homme fossile; Alger 1952. Italie par A. C. Blanc et S. Sergi, page 115.)
>
> The mandible, a very tough one, belongs to an adult. It is incomplete. The body, fairly well preserved on the right side, appears somewhat decayed on the left side. The third left molar is the only tooth present. All other teeth have been lost after death and the respective alveolar regions

> appear greatly injured. The first left molar was lost during life and an ample ossification fills the corresponding alveolar region. The left branch is wholly destroyed. The right branch is only partially preserved in its anterior part."

The present material has been compared with some small unidentified fragments of mammalian bones found at the same soil level and in very close proximity to another specimen of paleanthropic mandible called "Circeo III." This last was discovered by the author, in 1950, in the external ossiferous wall of the above mentioned Guattari's grot (see: "Man," London, vol. 51, January 1951, Art. 7). A complete anthropological study of the "Circeo III" will be published shortly.

TECHNIQUE

The bone samples were fixed in a 10% formol solution. In this manner the organic matter contained in the samples appears to withstand the action of the decalcifying fluid better than when not so treated. After decalcification in 1% HNO_3, the pieces were embedded in paraffin. It was necessary to watch carefully the decalcifying procedure in order to avoid the loss of the scarce organic material. The paraffin blocks were cut and the sections, 5–8 μ thick, were separately and respectively submitted to the following stains: hematoxylin and eosin, Mallory's, van Gieson's, toluidine blue for metachromatic staining, and periodic acid-Schiff's stain. Some sections, after removal of paraffin, were mounted in water for examination under the polarizing microscope.

The organic substance obtained from the bone fragments found in proximity to the mandible "Circeo III" was treated in a Waring blendor, shadowed with chromium according to Wickoff ('49) and examined with the electron microscope of the Istituto Superiore di Sanità in Rome.

RESULTS

The histological sections, prepared from the decalcified bone samples belonging to the mandible "Circeo II," demonstrate a surprisingly well preserved lamellar structure. The finding is particularly remarkable in the unstained sections observed under the polarizing microscope (figs. 2 and 3). Here the lamellar structure is also concentrically arranged around empty spaces, probably corresponding to the vascular structures which have disappeared. In some sections the concentric lamellar feature appears like the cross section of an osteonic unit. Between the lamellae it can also be noted elongated, elliptical, empty figures likely to be interpreted as the spaces previously occupied by the osteocytes.

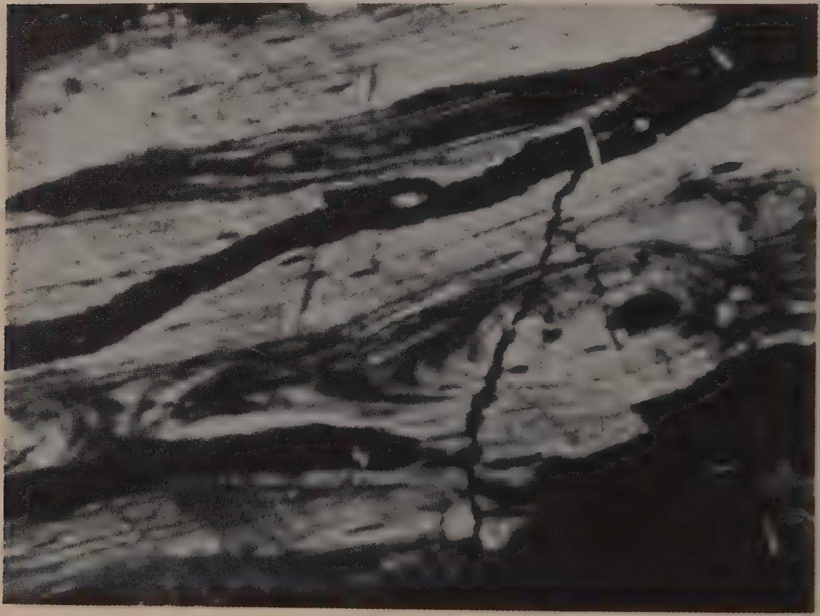


Fig. 2 Sample of "Circeo II." Section of decalcified bone at the polarizing microscope.

In some sections, signs of the tissue's deterioration are present (fig. 3). Indeed, the lamellae appear coarsely or thinly fragmented. Nevertheless the bi-refringence of the organic bone substance is strong, and to some extent agrees with that prepared from fresh bone. Such a finding testifies to the persistence of the collagen fibers.

The sections stained according to the above mentioned methods, demonstrate the same bone texture as that of those sections observed under the polarizing microscope. Besides, these sections demonstrate only the organic substance belonging to the bone's metaplasma. The osteocytes and the medullar cells have disappeared entirely. With hematoxylin-eosin, the bone's organic matrix is stained blue by the hematoxylin, but the intensity is very weak when compared with the hematoxylin affinity of decalcified fresh bone. In the same way the metachromasia with toluidine blue is present but is very transient and the sections quickly discolor. Shown in figure 4 is a section metachromatically stained with toluidine blue. The tissue texture is fibrillar in shape and two empty spaces previously occupied by osteocytes are evident. The fibrillar structure has been observed in each section. The slides stained according to

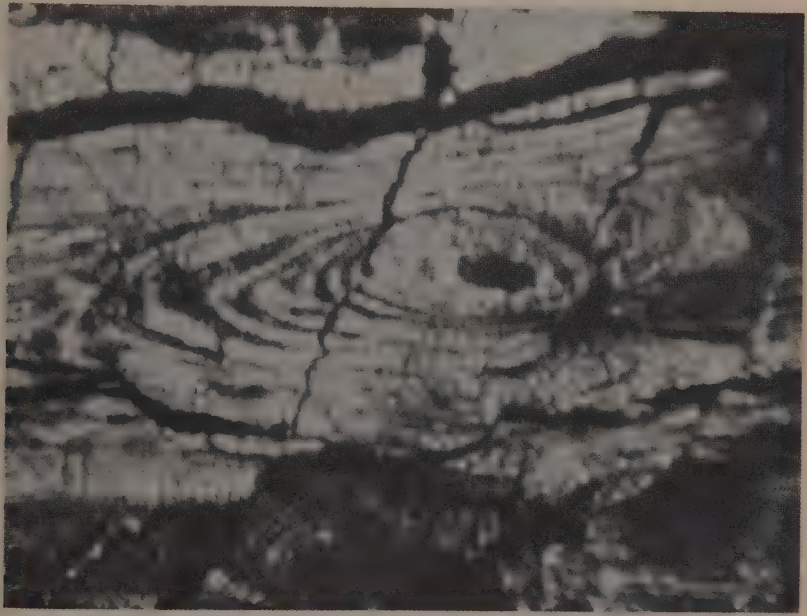
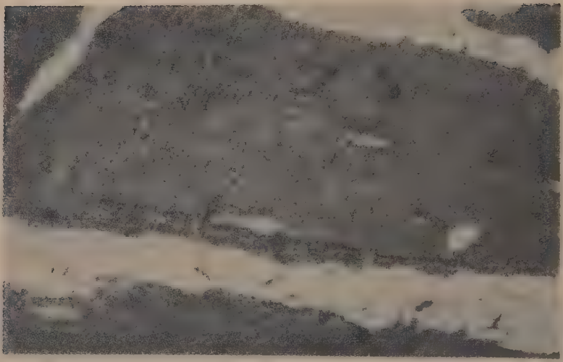


Fig. 3 "Circeo II." Another section of decalcified bone at the polarizing microscope. Signs of tissue's deterioration are present.



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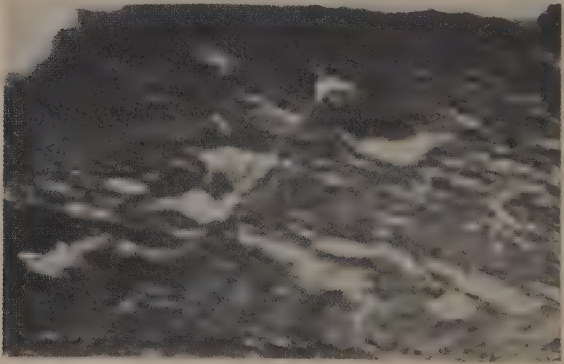

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Fig. 4 "Circeo II." Section of decalcified bone stained with toluidine blue for metachromasia.

Fig. 5 "Circeo II." Section of decalcified bone stained according to the Mallory method.

Fig. 6 Unidentified bone fragment found in close proximity with the mandible "Circeo III." Section of decalcified bone stained with periodic acid-Schiff's reagent.

Mallory's method (see fig. 5) reveal blue-purplish tonality. No section could be stained with periodic acid-Schiff's reagent.

The comparative study of the bone samples found in association with the mandible "Circeo III" disclosed the following features. The lamellar arrangement of the bone matrix is well preserved everywhere, while cells and vascular structures are not demonstrable. The tissue's bi-refringence is strong. The sections are weakly stained by hematoxylin, but the metachromatic reaction is persistent. With Mallory's and van Gieson's stains, the bone matrix shows respectively a blue-purplish tonality and a red color. The periodic acid-Schiff's reaction is positive but very weak (fig. 6).

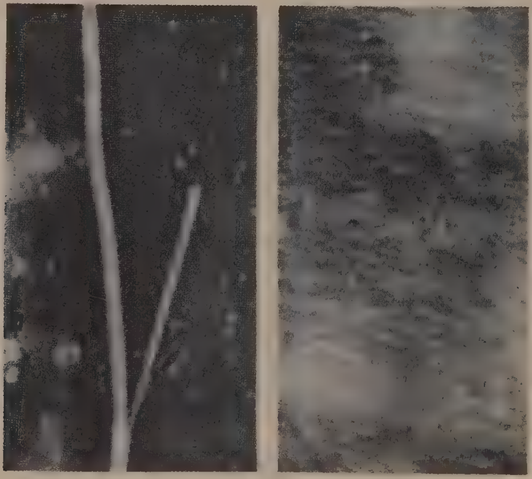
The more abundant organic material prepared from these last bone samples, which was not possible with the mandible "Circeo II," allowed an investigation with the electron microscope. By this method it was possible to demonstrate, in agreement with the strong bi-refringence of the tissue, the presence of collagen fibers with their 640 Å striation (see fig. 7A). Furthermore, the interfibrillar ground substance showed a very fine granular texture (fig. 7B) similar to that of fresh bone (Ascenzi and Benedetti, '54).

On the whole, the present investigations appear to show proof of the persistence of organic matrix in Neandertalian bones. The changes in the stain affinity and in the histochemical behavior are only to be ascribed to the conditions of the tissue's preservation. In such a way the weak hematoxylin affinity as well as the metachromasia fugacity and the negativity of the periodic acid-Schiff's reaction may essentially be inferred from the chemical changes of the polysaccharides belonging to the ground substance.

The quantitative histochemical differences in the behavior of the organic bone matrix, respectively obtained from the mandible "Circeo II" and the bone samples found in close proximity to the mandible "Circeo III," suggests the relatively better preservation of these last.

However, the preservation state alone does not allow any conclusions to be drawn on the relative geological age of the above mentioned bones. In fact, the bone preservation is not only a function of time, but also of the nature of the soil, local mesological conditions, and other factors.

The absence of organic matrix histologically demonstrable in the Neandertalian skull "Saccopastore II" (see Ascenzi, '49) should stand to indicate, to some extent, the appartenance of the same skull to an older period with respect to the mandible "Circeo II." This would agree with the results of the geological studies.



A B

Fig. 7 Unidentified bone fragment found in close proximity with the mandible "Circeo III." Electron micrograph of decalcified bone.

A Two collagen fibrils with the 640 Å periodic striations. (Magnification: × 22,000.)

B The very fine granular shape of the ground substance. (Magnification: × 40,000.)

CONCLUSIONS

1. For the first time, the presence of histologically demonstrable organic matrix in a Neandertalian bone has been proven to exist in the mandible "Circeo II." The same matrix shows a lamellar arrangement with some osteonic units.

2. Under the polarizing microscope the organic substance indirectly reveals the existence of a collagen texture. The

stain affinity and the histochemical behavior are somewhat changed with respect to fresh bone, i.e. weak hematoxylin affinity, fugacity of the metachromasia and negativity of the periodic acid-Schiff's reaction.

3. Also, the bone samples found in close proximity to the mandible "Circeo III" show the presence of organic bone matrix with collagen fibers that are directly demonstrable under the electron microscope. According to the histochemical behavior (persistence of the metachromasia, weak positivity of the periodic acid-Schiff's reaction) the organic matrix prepared from the last samples reveals a better preservation with respect to that which was obtained from "Circeo II."

4. Histochemical reactions appear as a suitable technique in establishing the state of preservation of the organic matrix present in "so called" fossil bones.

ACKNOWLEDGMENT

The author is indebted to Professor S. Sergi for the intrusting of the very precious material, and for the suggestions and assistance in the present study.

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SKELETAL AGE AT DEATH: THE RELIABILITY OF CRANIAL AND PUBIC AGE INDICATORS

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TWENTY-EIGHT FIGURES

INTRODUCTION

The exact chronological age at death of an individual skeleton has recently assumed importance due to the dynamic approach now introduced into anthropometrical analyses. It is believed that by utilizing the ages of a skeletal population, estimates can be made of the size of the breeding group, of mortality rates, of childhood survival, of child-birth deaths, etc. Ages of individuals under 25 years can be calculated with relative accuracy, based on the order of epiphysis-diaphysis closure of the long bones; the order of tooth eruption from infancy to about 17 to 20 years; the closure of the spheno-occipital suture before 20, or at the least, 25 years; and the union of the medial clavicular epiphysis between 25 and 28 years. In a skeletal series then, the question is how to make observations on age of death of adult individuals of 28 years and older. Determination of the actual age of an adult skeleton at time of death was a problem which interested T. W. Todd, and one which he and his students attacked by various methods. They wished to obtain a simple and exact means of determining the age of the osseous skeleton by its morphology, and as anatomists they did not interest themselves in the age factor as applied to the statistics of ancient populations. The method of determining age by cranial suture closure has always been more generally used, due not only to the greater interest in the skull, but also because the cranium is frequently the best preserved portion of the archaeologically recovered skeleton. When in recent years population dynamics entered into anthropometrical analyses of archaeological skeletal material, it was noted that the ages obtained from cranial suture closure either produce skewed mortality rates (Şenyürek, '47) or do not correlate with the known age of death (Singer, '53).

At the suggestion of Dr. Theodore D. McCown, of the University of California, Department of Anthropology, an inquiry was begun into the reason why samples of aboriginal California Indians showed a mean age at death consistently under 30 years. The method was twofold: (1) to utilize both of Todd's methods of age determination, that of cranial suture closure as well as that of morphological changes occurring at the symphyseal surface of the pubis with advancing age, observing whether or not these methods are applicable to races other than the white and negro-white with which he had worked; (2) to determine the correlation between these two methods of obtaining age when applied to one individual.

The reason for selecting these two methods only and not including the age changes in the scapula (Graves, '22) and the clavicle (Stevenson, '24; Todd and d'Errico, '28) is that the chosen determinants can be utilized for the ages from 18 to 50 plus years, while clavicular and scapular ages only set a point in time with a margin of perhaps 5 ± years. The first of Todd's methods of determining the age of an individual is based on the progressive morphological changes of the symphyseal face of the pubis. These changes he divided into 10 phases, the first three phases representing two to three year spans; the next phases, through Phase IX, containing 5 years or more; and Phase X including all ages over 50 years. In a series of papers, published in the early 1920's (see Bibliography) he described the appearance of the symphyseal face, at the approximate mid-point of each phase, for males and females of white and negro-white races. The differences between the groups were not sufficiently distinct to preclude using the same morphological changes for all 4 groups. Shortly after this, 1925, Todd and D. W. Lyon re-defined the method of age determination by endocranial and ectocranial suture closure, working with the same skeletal material which Todd had used previously. No report has been found of an attempt to correlate the two methods with each other. They were apparently evolved separately and checked only against the known age, which is available for the skeletal series at Western Reserve University (referred to in this paper as the WRU series).

DESCRIPTION OF THE UCMA AND WRU SERIES

In the Spring of 1948, Professor Edward W. Gifford, Director of the University of California Museum of Anthropology, made provision for the author's research with the archaeological skeletal collection of the Museum (referred to in this paper as UCMA series). At that time the California archaeological collection consisted of approximately 5,000 catalogue numbers. The minimum requirements for consideration of a skeleton were (1) that it be over 18 years of age, as judged by long bone epiphysis-diaphysis union and fusion of the three elements of the hip bone in the acetabulum; (2) that there be present at least the area of the three vault sutures, coronal, sagittal and lambdoid; and (3) that there be preserved a symphyseal surface of one pubic bone. As each catalogue number usually represents an archaeological burial, the bones numbered and classified together are presumed to represent one individual and in cases of doubt, that burial was not included in the series. No consideration was made of area or archaelogical horizon, but all the skeletons are from California. This gave a sample of somewhat under 400 individual skeletons. In 1953 a second series of about 70 skeletons was analyzed, using the same qualifications, as a check on the method (the histograms of this second series are shown in figure 3, but the series is not included in the tabulation of table 1). After a careful survey and consultation with T. D. McCown, a series of 10 pubes was selected (referred to in this paper as Brooks' models), which matched the written description of Todd of his 10 pubic phases (Todd, '20). They were chosen to represent cross sections taken from the continuum of the morphological change processes of an individual life cycle. Dr. Russell W. Newman modeled this series in dental stone (pl. 3, figs. 18–22 and pl. 4, figs. 23, 24, 26 and 27). For cranial age determination the charts published in Todd and Lyon's paper ('25) were relied on, which indicate expected closure by age for each suture. The amount of closure is defined numerically on a 4-point scale: 0 (open) to 4 (complete) closure. Todd and Lyon analyzed separately endo- and ectocranial suture closure. In working with the archaeologically recovered crania, frequently there is an internal patination of the cranium and even when there is not, it is difficult to see more than the vault sutures in a whole skull. The WRU crania have been sectioned either sagittally or above the orbits, so that endocranial observations are possible. The term ''cranial'' when used in reference to the UCMA series or to part of the analysis of the WRU series means all visible endocranial suture closure averaged with ectocranial suture closure. The sex differentiation was based on S. L. Washburn's application ('48) of the ischio-pubic index wherever this was possible, as well as on the breadth of the sciatic notch, the sub-pubic angle, and the general configuration of the skull and mandible. When analyzing the UCMA skeletal series, first the pubic age determinations were made, working through all the catalogue numbers. Then the recording of the cranially determined ages was begun. Not until the work was finished were the two estimated ages of the individual skeletons compared.

In the Spring of 1950 a University of California research grant made it possible to utilize the Hamann Museum collections of skeletons at Western Reserve University. Known age at death, sex, and Todd's estimated pubic and endocranial ages are recorded for this series. With the help of Dr. William H. Sassaman, Dr. Normand L. Hoerr, and Dr. Idell Pyle all the white female and most of the white male skeletons on which Todd had based his results were reviewed. Since the crania are stored separately from the postcranial skeletons, completely independent assessments were made of cranial and pubic ages. Doctor Sassaman was kind enough to loan the original models which Todd had used, illustrated in the *American Journal of Physical Anthropology* in 1920–21. These were used in conjunction with Brooks's models, after first recording pubic ages with the latter models alone. Both of these sets of age determinations varied from each other less than a year or so either way. Photographs of Brooks' models (pls. 3–4, figs. 18–28) and of Todd's models (pls. 1–2, figs. 8–17) show that the sets resemble each other closely. The WRU series is not a random sample, but deliberately selected by the author so that each pubic phase has approximately the same number of individual skeletons whose known age falls within that span. This was done as a test check for the correlation of Todd's pubic and cranial age, Brooks' pubic and cranial age and the known age.

PRELIMINARY ANALYSIS OF THE DATA

Various procedures were used in analyzing these data, but only those relevant to the problem of correlating the two methods of age determination are discussed here. In considering the UCMA series, it is immediately apparent that there is no way of checking the accuracy of either cranial or pubic ages should they be divergent in one individual, except by an indirect approach. The age indicators apparent in the entire skeleton were eliminated at the outset because the definition of the problem deliberately limited the work to an analysis of only cranial and pubic age determinations as circumscribed by Todd and Lyon. The purpose is to isolate these bones, treating them as single variables and to disregard the rest of the skeleton. The attempt is comparable to the palaeontologist's method of relying on a fossil genus or species, which is restricted to one geological stage. These type-fossils are geological age indicators: Can the particular morphological appearance of certain human bones be considered reliable age indicators in the same way as these type-fossils? The mean ages were calculated for the male and female series, cranial and pubic ages separately, and appraised through ethnological information for their probable errors. Histograms were also plotted showing the distribution of cranial and pubic ages by sex. These histograms presumably reflect mortality rates among the California Indians archaeologically. The WRU series, having a known age factor, is the base sample that actually confirms the conclusions which were originally demonstrated by the UCMA series.

TABLE 1

Age characteristics of the UCMA and WRU series

		WRU SERIES				UCMA SERIES	
		Male		Female		Male	Female
Observer		TWT	STB	TWT	STB	STB	STB
Total number in series		100	103	26	82	194	177
COEFFICIENTS OF CORRELATION	Pubic and known age	.91	.87	.67	.72	...	...
	Endocranial and known age	.78	.74	.56	.41	...	...
	Pubic and endocranial age	.80	.73	.58	.40	...	...
	Cranial and known age	..	.71	..	.38	...	...
	Cranial and pubic age	..	.65	..	.33	.39	.38
Mean cranial age		..	..	..	..	31.8 ± .50	29.7 ± .49
Mean pubic age		..	..	..	..	33.3 ± .58	39.6 ± .80
Mean of individual deviation of cranial from pubic age		..	..	..	..	± 6.5	± 11.6
Mean of individual excess of pubic over cranial age		..	..	..	..	+ 1.6	+ 9.7

The UCMA series illustrates the sharp deviation between ages in the female skeleton determined on the basis of cranial suture closure and pubic face pattern. The histogram (fig. 2) of the UCMA female series has two points of high frequency, the cranial age mode at Phase IV, or 24–26 years, and the pubic age mode at Phases IX and X, or 45 to 50.

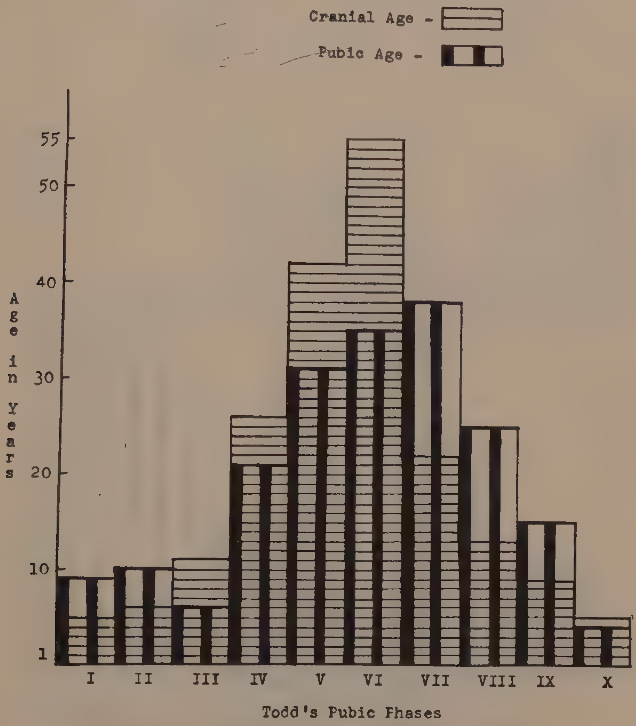

Fig. 1 Mortality curve, UCMA male.

There is a 10 year difference (table 1) between the female pubic mean age and that of the cranial age. These findings are very similar to those of Şenyürek ('47), who refers to the "slower rate of sutural union" in females of an ancient Anatolian population. The female cranial suture closure tends to lag from 5 to 25 years, with a mean of ± 9.7, behind the age changes observed in the pubic bone. The histogram (fig. 3), representing the second series analyzed about three years later, has the same configuration as the original UCMA female series.

The data obtained from the UCMA male series are not similar to the female series and show a somewhat higher correlation between cranial and pubic ages. There is approximately two years average difference between ages determined

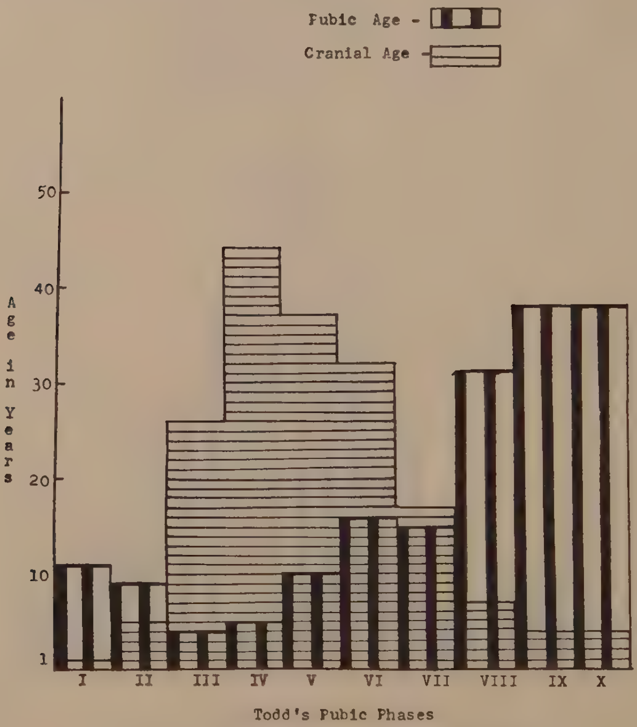

Fig. 2 Mortality curve, UCMA female.

from cranial suture closure and pubic face pattern (table 1), also apparent in the overlapping modes in the histogram of the male series (fig. 1). In males, the age calculated from suture closure tends to deviate not more than plus or minus 5 to 8 years (table 1), from the age obtained from the pubic face pattern. The histogram (fig 3) plotted from the second UCMA series corroborates the original data. If this is a personal error, it is consistent. However, after noting the similarity between Todd's pubic models (figs. 8–17), based on the WRU white male series, and Brooks' California Indian models (figs. 18–28), it appears plausible that this is not a personal error, since Brooks' pubic types, taken from Todd's written descriptions, match Todd's original models so well. Furthermore, it cannot be easily explained on the basis of racial differences. When Todd's WRU series were evaluated both male and female cranial age determinations show lack of correlation with the known age. Although Todd did not publish tables of correlations between his estimated

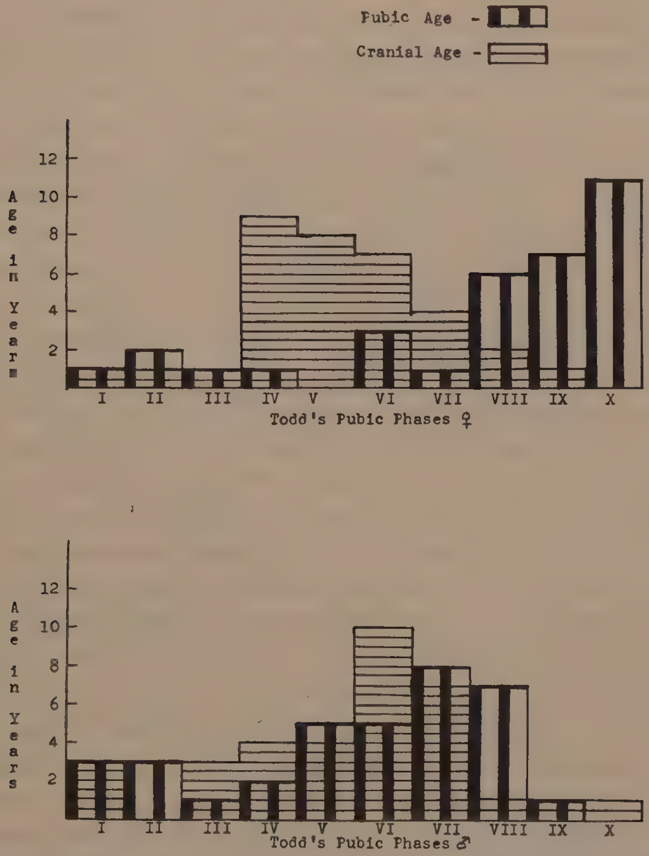

Fig. 3 Mortality curves, UCMA second series, male and female.

endocranial age and known age, he did warn his readers that even endocranial age, which he believed to be more reliable than ectocranial age, had a range of error of at least plus or minus 10 years.

The UCMA histogram for the female series shows the highest frequencies of the cranial curve at the ages of 24–26 years. Considering the histogram as a mortality curve, the highest mortality rate occurring during the years of 24–26 is not at all concomitant with ethnological descriptions of California Indian villages in which a high percentage of women lived to ages well over 40 or 45 years (see Bancroft, Dubois, Foster, Gayton, Kroeber, Powers). Moreover it does not fit the high mortality frequency of American Indian females in the age groups over 41 years as cited by Clark Wissler ('42). The female pubic age curve does not seem more accurate. According to research carried out by Wissler ('36), and especially by Clements ('31) and Krogman ('35) on American Indian vital statistics, the male pubic age histogram is a closer approximation than the UCMA female histograms to the type of American Indian mortality curve. The grouping of all ages over 50 years into one category creates a minor distortion that, however, does not affect the major comparisons of the crucial adult ages from 25 to 50.

The WRU series, both Todd's and Brooks', were examined from several different points of view. Regression coordinates were plotted for all groups within both series. They are not presented here as the table (table 1) of coefficients of correlation presents the same data in a more compact manner. In effect, Todd's coefficients and Brooks' are very similar for the WRU series. Coefficients of correlation for the UCMA series are included here to complete the tabulation, and they coincide exactly with the more directly derived results. Todd and Brooks show a very high correlation between ages determined from pubic face pattern and known age for males. The figures are nearly 20 points lower in the female group, although the correlation is sufficiently high to be significant. Male endocranial and known age coefficients of correlation are not as high as the pubic and known age correlations, but they are not below statistical significance. Endocranial and known age correlations are extremely low in both series of females. Thus, the WRU series corroborates the UCMA data: the male pubic age seems to be quite accurate, the female pubic age less so, and the cranial age, in both males and females, especially the latter, of dubious reliability.

RESULTS OF THE SCATTER DIAGRAMS

Shortly after completing the second UCMA series, it was decided to re-analyze the WRU data before beginning research on the problem of age determination in the whole skeleton. The WRU series was plotted on scatter diagrams, pubic age being the X-coordinate and cranial age the Y-coordinate. The known age, being an absolute, was plotted as a diagonal line. If the conclusions stated above are correct, the diagrams would show this as clearly as all the other tests had. Regrettably for the conclusions, the WRU diagrams show a much more complex and not very encouraging picture (fig. 4). At the University of California Statistical Laboratory it was decided that the tests previously applied to the WRU material are not valid methods for checking this type of data. The histograms for the UCMA series and the scatter diagrams for the WRU series were merely an approach to the correct evaluation of this qualitative type of analysis. The formulae that produce coefficients of correlation, standard deviations and regression coordinates, tend to distort such data as are presented here, where each individual age is an estimated figure with a plus or minus range of a year or more. Mohamad S. Ahmed, of the University of California Statistical Laboratory, re-analyzed the WRU series (table 2, figs. 5 and 6). He allowed each qualitatively analyzed age determination to represent itself against the known age for that individual on two graphs, one for pubic and one for cranial age. Thus, his conclusions, though startling, are factual and a base for further research into the question of the validity of age indicators.

Phase X is not included in the graphs since it has no upper limits and is more or less unreliable in an analysis which is determining group limits. The pubic age graph (fig. 5) is plotted with the known age as the X-coordinate and Phases I through IX as the Y-coordinate. Rectangles were then drawn "whose sides parallel to the Y-axis, representing the groups, are of fixed length; and the other sides parallel to

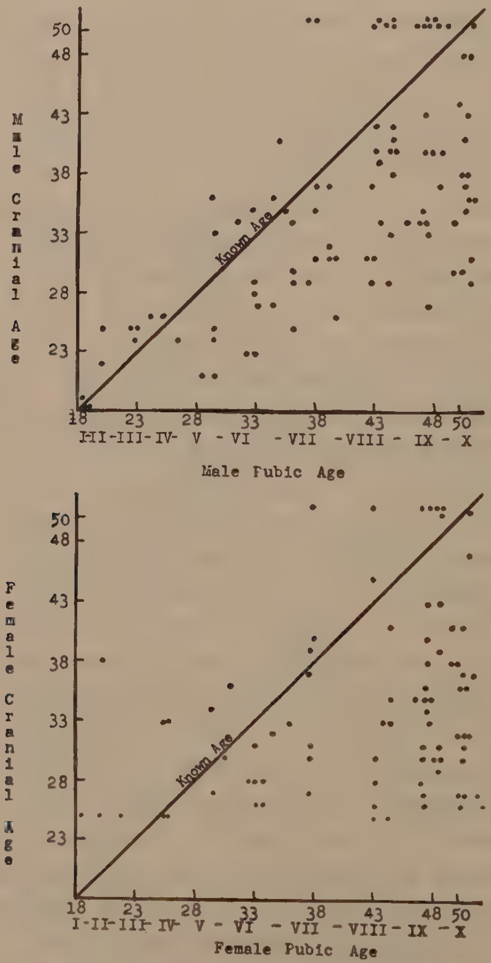

Fig. 4 Scatter diagrams, WRU, male and female. Roman numerals indicate Todd's pubic stages.

the X-axis are chosen in such a way that on the whole the rectangles cover as many points as possible, without overlapping of the age limits'' (letter of February 16, 1954, from M. S. Ahmed). The cranial age graph (fig. 6) is plotted with

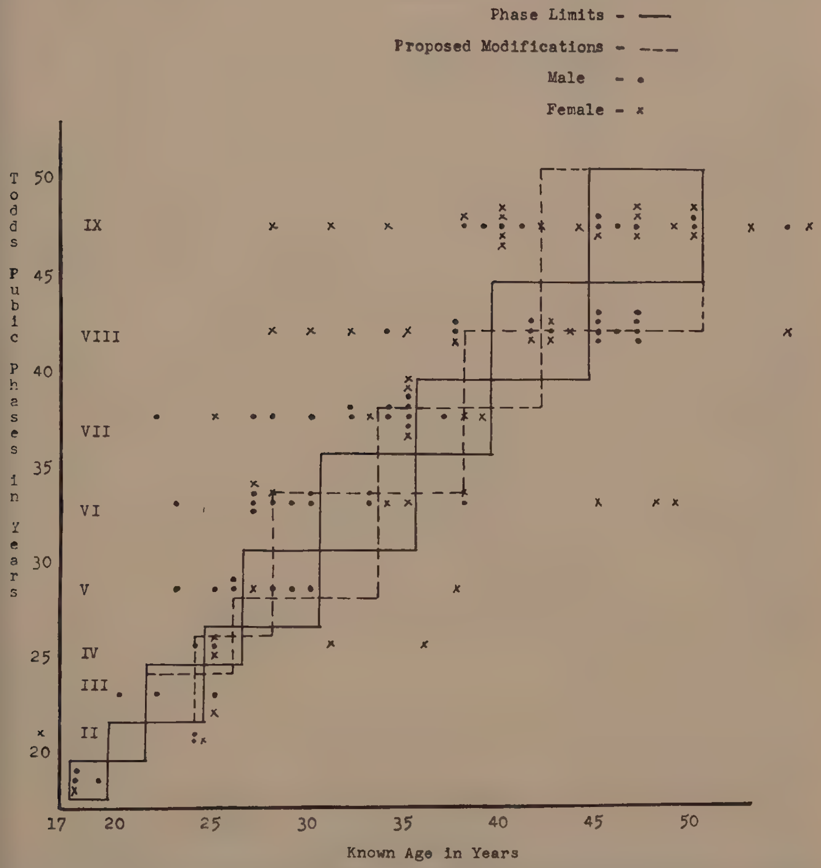

Fig. 5 Scatter diagram of pubic age (STB) and known age of WRU, male and female.

the known age as the X-coordinate, and the predicted age based on cranial suture closure as the Y-coordinate. Since in the pubic graph (fig. 5), ''the side of the largest rectangle used in these solutions is 7 years, hence for the purpose of comparison giving the best chance to the method based on cranial measurements, the predictions based on cranial measurements are taken to be ± 3.5 years ... two lines were drawn parallel and on opposite sides of the bisector at a vertical distance of 3.5 years from the bisector and the number of points within this band was noted. This number gives the total number of correct predictions for the method based on cranial'' (from letter cited above) suture closure.

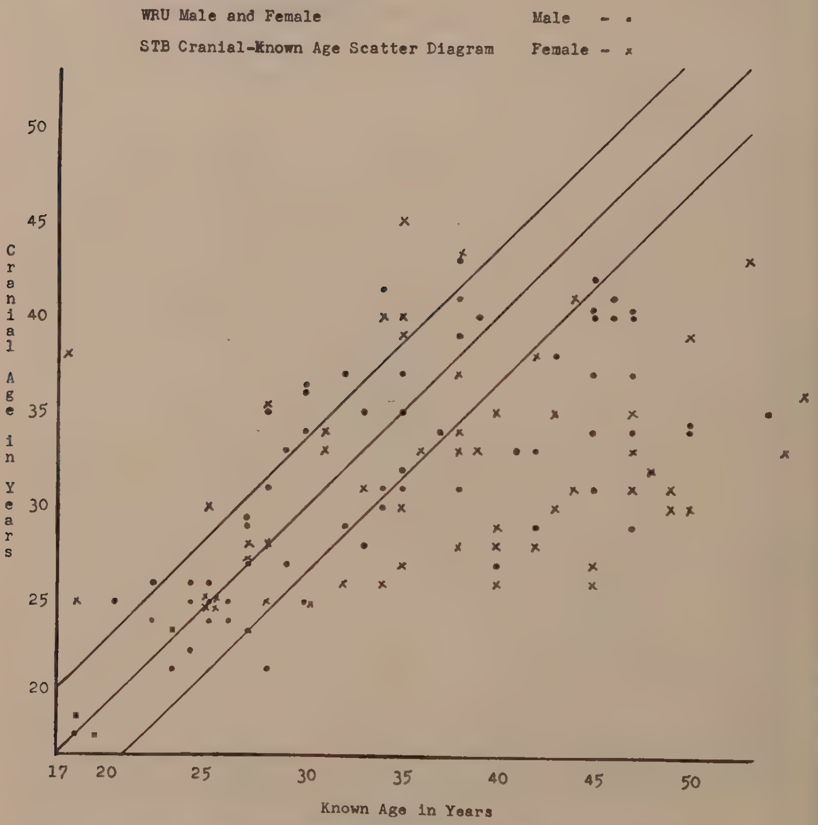

Fig. 6 Scatter diagram of cranial age (STB) and known age of WRU, male and female.

As can be seen in table 2 the percentages of correct prediction for male and female, cranial and pubic age determination, are less than 50%. Ahmed has suggested that if the limits of the phases were to overlap the percentage of correct prediction of age based on the pubic face in the male would be increased to 72%. This is not the desired solution, since a concise series of age indicators the limits of which do not overlap is sought — in fact even Todd's overlapping of Phases V, VI and VII by one year each, has been criticized. Ahmed has also suggested a modification of the age limits (table 2) which shifts Phases V through VIII making them about three years younger. This is to accommodate the consistent underageing graphically shown in figure 5.

When Todd's pubic data are graphed the same way, similar disparities appear (fig. 7). The patterning as a whole is somewhat better than Brooks', but the percentage of correct prediction is only 54% for males and 31% for females. In part the reason for the low pubic percentages is due to the disparateness created by the rectangular units in the graph; the continuum of parallel bands in the cranial graph (fig. 6) creates a slightly higher total of percentage predictions by including all points outside the bisector by 3.5 years. There is a possibility that Ahmed's modified limits would also increase the accuracy of Todd's predictions to 60–70%. The potential improvement in these modified limits should not be overlooked, since over 60% correct prediction of male ages by only one skeletal age indicator is an unexpectably high per cent.

Recently Singer ('53) published a critical account on the inaccuracies of age determinations through cranial suture closure. His comments and conclusions are in accord with the results derived from both the UCMA and the WRU series of cranial age determinations. The female groups had much greater discrepancies than the male groups in the WRU series between age determined from cranial suture closure and known age. The tendency is for cranial sutures of female individuals to remain open, either throughout life, or to close much later than predictions based on present age determination methods. This trait of unclosed cranial sutures in the female is present also to a certain extent in male sutures. Frequently, in both the WRU and UCMA series, skulls were found whose vault sutures were completely united, indicating a minimum age of 46 years, and the circummeatal sutures were open, indicating a maximum age of 37 — years. More often all the sutures were open, giving an age prediction

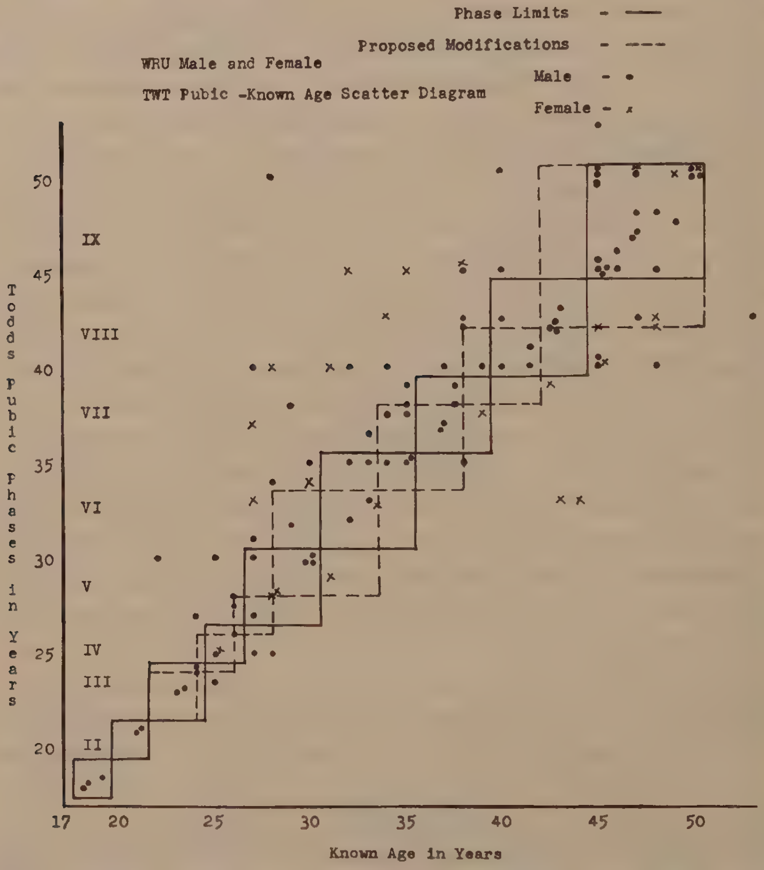

Fig. 7 Scatter diagram of pubic age (TWT) and known age of WRU, male and female.

of under 25, when tooth wear and decay, clavicular epiphysis closure, scapular lipping, and the symphyseal surface of the pubis indicated an age well over 35 years. In such cases in the WRU series, the known age established the reliability of these other age indicators and, thus, the lack of validity of cranial suture closure as an age determinant. This evidence, combined with Singer's data based on Cape Coloured and White German, seems to be more than adequate to recommend that cranial suture closure be considered an unreliable age indicator, regardless of sex or race.

TABLE 2

Based on WRU series. Limits of pubic phases

PUBIC PHASE	AGE LIMITS ACCORDING TO TWT	MODIFIED LIMITS	OVERLAPPING LIMITS
I	17.5–19.5	17.5–19.5	17.0–20.0
II	19.5–21.5	19.5–21.5	19.0–22.0
III	21.5–24.5	21.5–24.0	20.0–25.0
IV	24.5–26.5	24.0–26.0	23.0–27.0
V	26.5–30.5	26.0–27.0	25.0–30.0
VI	30.5–35.5	27.0–33.5	27.0–35.0
VII	35.5–39.5	33.5–38.0	34.0–41.0
VIII	39.5–44.5	38.0–42.0	40.0–47.0
IX	44.5–50.5	42.0–50.5	45.0–50.0
X	50.5	50.5	48.0

Percentage of correct prediction

SEX	TWT PHASE LIMITS	MODIFIED LIMITS	OVERLAPPING	CRANIAL SUTURE CLOSURE
Male STB	30	61	72	45
Female STB	35	39	45	26
Male TWT	54	. .	. .	. .
Female TWT	31	. .	. .	. .

ALTERNATIVE PATTERNS OF METAMORPHOSIS OF THE PUBIC SYMPHYSEAL FACE

This limitation of the value of ages determined from cranial suture closure makes it necessary to inquire why the ages determined from pubic face pattern for the WRU series, both Todd's and Brooks', have such a low percentage of correct prediction. A close look at figures 5 and 7 show that many of the individual ages, especially in the male sample, are too young by only a few years. Ahmed believed that the modified age groups would correct this error of underageing. There are other factors in utilizing the symphyseal surface of the pubis as an age indicator which Todd ('23) discussed. In his early work, 1920–21, Todd delineated the progressive morphological changes that occur on the symphyseal face of the pubis, from age 18 to 50 plus years. The actual models (figs. 8–28), both Todd's and Brooks's, were chosen to represent the midpoint of each of his 10 phases. In both series. some models deviate from the original description of the central tendency, but in utilizing the models allowance may have been made for such deviations. In addition to these described phases, which are perhaps the most usual appearances for these ages, there are alternative morphological patterns with other contours to the pubic face. Some of these alternative patterns have been described by Todd ('23), one is described below, and there are others which have not yet been analyzed.

Todd grouped his 10 phases into three general categories. The first includes Phases I–III, the post-adolescent stages. The second consists of Phases IV–VI, during which the outline of the symphyseal surface is built up. The third covers Phases VII–X, the period of gradual quiescence and later break down (Todd, '20, '21). To the phases which represent build-up, IV through VI, Todd later ('23) added other patterns of metamorphosis. These alternative morphological patterns he called the ''anthropoid strain,'' ''regressive strain'' and an intermediate type. They are not successive stages of any of the 10 standard phases, but rather morphological changes alternative to the more usual patterns. One more variation from the norm has been found and is described here; it is called the ''rough'' type as opposed to the more frequent ''smooth'' type, which occurs in the original series. This rough type was discovered while working with the WRU material, so an absolute check on age was obtained. A subsequent re-examination of the California Indian material proved the rough type to be present here also.

The rough type had been previously mistaken for an anomalous Phase X, so the observational difference between the two patterns rests on the recognition of the difference between the break-down of old bone and the appearance of a new surface of smooth bone moving dorso-ventrally over the previous young surface of a Phase IV symphyseal face. The rough type first appears clearly in late Phase V or early Phase VI. During Phases VI and early VII, there is to be seen a smooth layer extending from the dorsal edge about half way over the symphyseal face (fig. 25). There has been built up the characteristic third period edge at the dorsal rim as well as at the cranial and caudal margins, if it has extended to them. Where this smooth encroaching layer ends, there is an abrupt declivity, the length of which is usually crenulated. Not yet covered by this ''escarpment,'' which extends from the cranial to the caudal margins of the symphyseal face, can be seen the somewhat rippled surface which is characteristic of the post-adolescent period. This young symphyseal face generally can still be seen caudad, merging into the inferior ramus of the pubis, and craniad, extending toward the pubic tubercle; there is no definition of the ventral edge, although it is beveled as Todd describes for Phases III and IV, and neither cranial nor caudal margins are delineated.

There are other patterns of pubic metamorphosis which have not been recorded. In particular among female pubic bones, there is a pattern which gives the appearance of age due to the excessive slenderness of the symphyseal face. The complete change of the symphyseal face from Phases IV through VII, gives ample opportunity for morphological variations, though certainly none of the phases of the pubic metamorphosis is static. Todd's anthropoid and regressive types as well as the rough and smooth types are quite different in their patterning. Further work is needed to record the frequencies, racial and sexual, of the alternative patterns of pubic metamorphosis, as well as to check the occurrence of other patterns. There have been noted frequently certain apparent pathologies, such as a ''puffy'' and ''swollen'' appearance of the symphyseal face, the persistence of the junction lines of the ischial and iliac epiphyses well into adulthood, and an apparent static quality with certain features of a young phase being carried into an older one.

Long before Todd defined his methods of age determination an error was made by believing that skeletal age could be calculated from one bone, or perhaps from the cranium, alone. The fact that individual bones are not isolates seems to have been ignored. The laboratory skeleton was once a part of a living entity on which debilitating changes with time, accidents and death have left their marks. There is no doubt that certain parts of the skeleton can be looked upon as age indicators because of their physiological-anatomical functions. The epiphysis-diaphysis union, which is known to be a valid sub-adult age indicator (Greulich and Pyle, '50) has a causative relationship with growth hormones and the physiological factors of increasing age. Todd ('21) has said that the pubic symphysis represents an incomplete epiphysis-diaphysis union. The fusing bony nodules which occur in Phases III through V, are epiphyseal in origin. This is why Todd chose the symphyseal surface of the pubis as an age indicator. It is also why through modification of the age limits of phases and amplifications of the phases themselves, the symphyseal surface of the pubis can be made into one of the more reliable age indicators for adult skeletal material. Age of an individual, where there is a whole or partial skeleton, should never be determined on the basis of one age indicator, no matter how reliable. There are always possibilities of arthritis, bone tuberculosis, osteomyelitis, etc., which can alter a single bone or a whole skeleton.

Problems of alternative patterns of pubic metamorphosis are still unsolved. They should not be analyzed as isolates, however. Future research should deal with all the changes to the skeleton created by advancing age in the individual over 18 years. The method of age determination of an individual over 18 years would then include the union of the iliac and ischial epiphyses, fusion of the medial clavicular epiphysis, age changes in the scapula, the age patterns of the pubic face and of other articular surfaces, wear and decay of the teeth, arthritic and other age changes in the vertebral column, and also cranial suture closure. Certain items in this list can only be utilized when considering skeletal material under 30 years, other items are usually applicable only to individuals over 35 or 40 years. Cranial suture closure, especially in male skeletal material, may be used as a secondary confirmation, with caution. The age changes of the symphyseal surface of the pubis, when correlated with the other skeletal age indicators, will probably be considered to be the major component in age determination. When the pubic face does not comply with Todd's illustrated phases and the remainder of the skeletal age indicators place the individual between the ages of 25 and 37 years, there is present one of the alternative morphological patterns. The frequency of such occurrences is relatively high in both sexes and even when these patternings have been established, the pubic phase is only a part of the whole skeleton.

SUMMARY

1. The validity of the closure of cranial sutures and morphology of the symphyseal surface of the pubis are considered as age indicators.
2. Both methods are utilized independently on three skeletal series: the University of California Museum of Anthropology archaeologically recovered California Indian skeletons, two series analyzed separately; the confirmatory data based on a series of skeletons from the Hamann Museum Collection at Western Reserve University.
3. The results of all three series are basically the same: male age estimates derived from the morphology of the pubic articular surface have high coefficients of correlation with the known age; female age estimates are slightly lower in their known age correlation; and, cranial age estimates, even

endocranially determined, correlated poorly and should be used only with caution.

4. The WRU series, both Brooks's and Todd's original data, are plotted on scatter diagrams, the known age as the ordinate and the pelvic age as the abscissa, and the percentage of correct prediction determined. These percentages are 54% for Todd's data and 30% for Brooks's. The diagrams also show a consistent overageing by pubic age estimates and when cranial age estimates are used, a constant underageing.

CONCLUSIONS

1. The age phases of the morphology of the symphyseal surface of the pubis should be modified according to the limits proposed by M. S. Ahmed, as these correct the overageing resulting from the original phase limits.

2. Should the articular face of the pubis present a morphological appearance not in accord with the standard descriptions of Todd, one of the alternative patterns of metamorphosis may be present. Todd has described three alternative patterns and another is included in this paper. In any series, should a variant type of symphyseal face appear with regularity, frequency of occurrence for male and female should be recorded.

3. Age estimates determined by cranial suture closure are unreliable. As an age indicator in female skeletons, cranial suture closure is doubtful, in males it should only be utilized as confirmatory to other indicators of adult age.

4. Even employing the modified limits of the pubic age phases, an age estimate for a skeleton should not be based on pubic morphology alone. The skeleton, *in vivo*, was a unit and when under analysis in a laboratory, should still be considered as a whole. No one age indicator is adequate.

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PLATE 1

EXPLANATION OF FIGURES

T. W. Todd's models of the symphyseal surface of the pubis.

8 Lower right. Phase I (age 18–19).

9 Center right. Phase II (age 20–21).

10 Upper right. Phase III (age 20–21).

11 Lower left. Phase IV (age 25–26).

12 Upper left. Phase V (age 27–30).

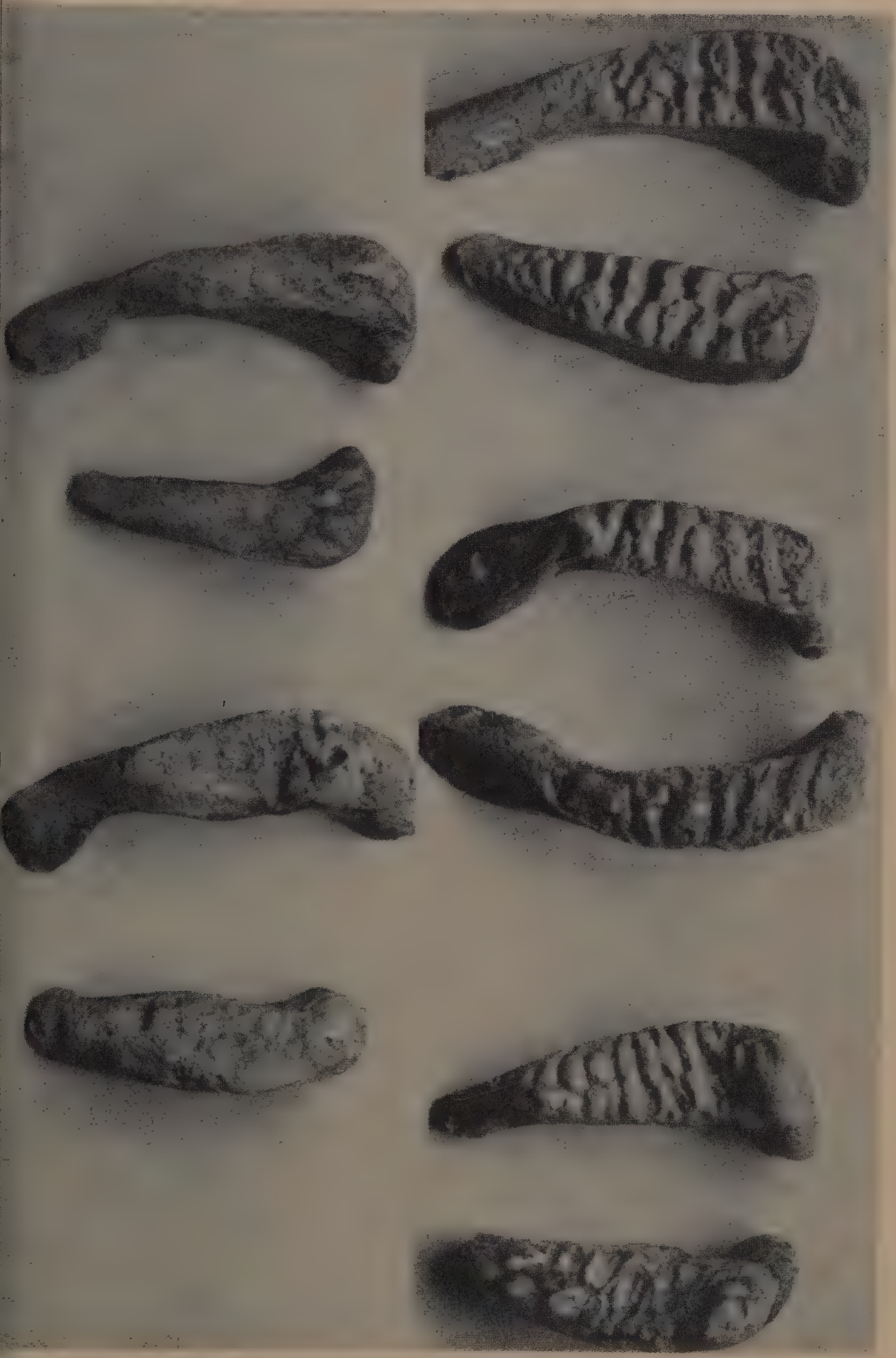

PLATE 2

EXPLANATION OF FIGURES

T. W. Todd's models of the symphyseal surface of the pubis.

13 Lower left. Phase VI (age 30–35).

14 Upper left. Phase VII (age 35–39).

15 Upper right. Phase VIII (age 39–44).

16 Center right. Phase IX (age 45–50).

17 Lower right. Phase X (age 50 and upward).

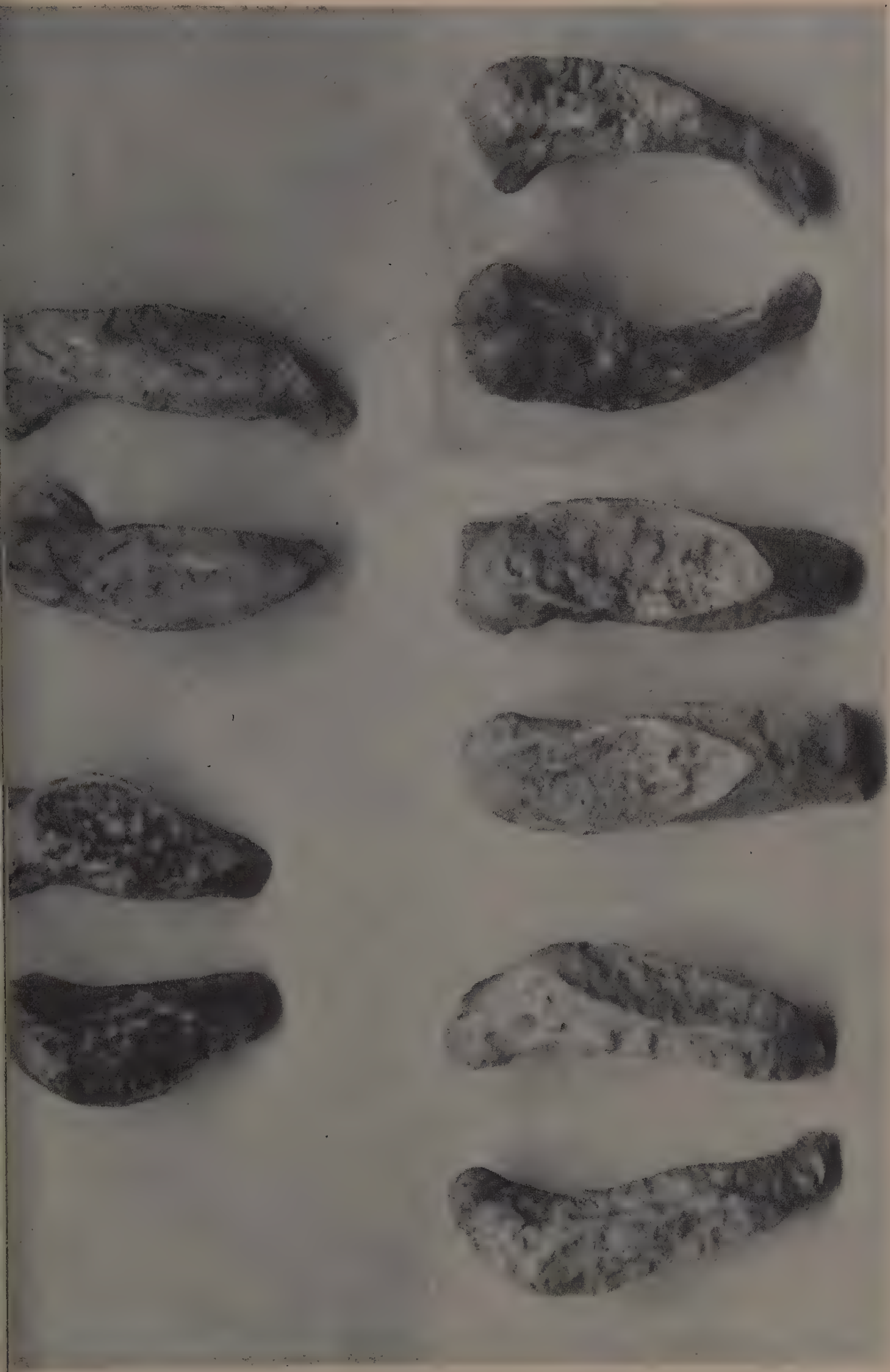

PLATE 3

EXPLANATION OF FIGURES

S. T. Brooks's models of the symphyseal surface of the pubis. Ages modified according to M. S. Ahmed.

18 Lower left. Phase I (age 17.5–19.5).

19 Upper left. Phase II (age 19.5–21.5).

20 Lower right. Phase III (age 21.5–24.0).

21 Center right. Phase IV (age 24.0–26.0).

22 Upper right. Phase V (age 26.0–27.0).

PLATE 3

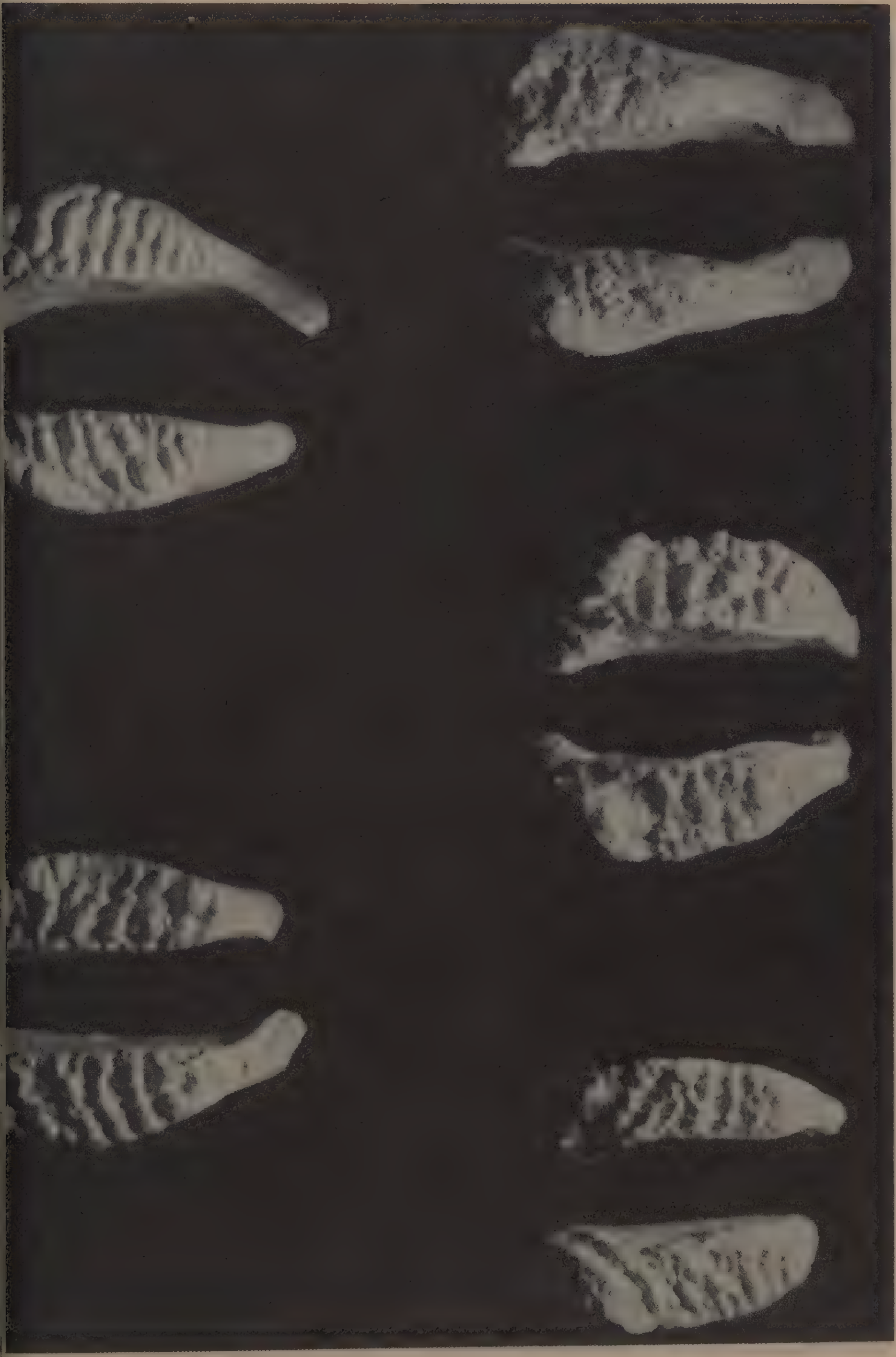

PLATE 4

EXPLANATION OF FIGURES

S. T. Brooks's models of the symphyseal surface of the pubis. Ages modified according to M. S. Ahmed.

23 Lower left. Phase VI, smooth type (age 27.0–33.5).

24 Center left. Phase VII, smooth type (age 33.5–38.0).

25 Upper left. Phase VI–VII, rough type (age 28.0–37.0).

26 Lower right. Phase VIII (age 38.0–42.0).

27 Center right. Phase IX (age 42.0–50.5).

28 Upper right. Phase X (age 50 and upward).

THE VARIABILITY OF THE TEMPORAL LINES, ITS CAUSES AND EFFECTS

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FOUR FIGURES

INTRODUCTION

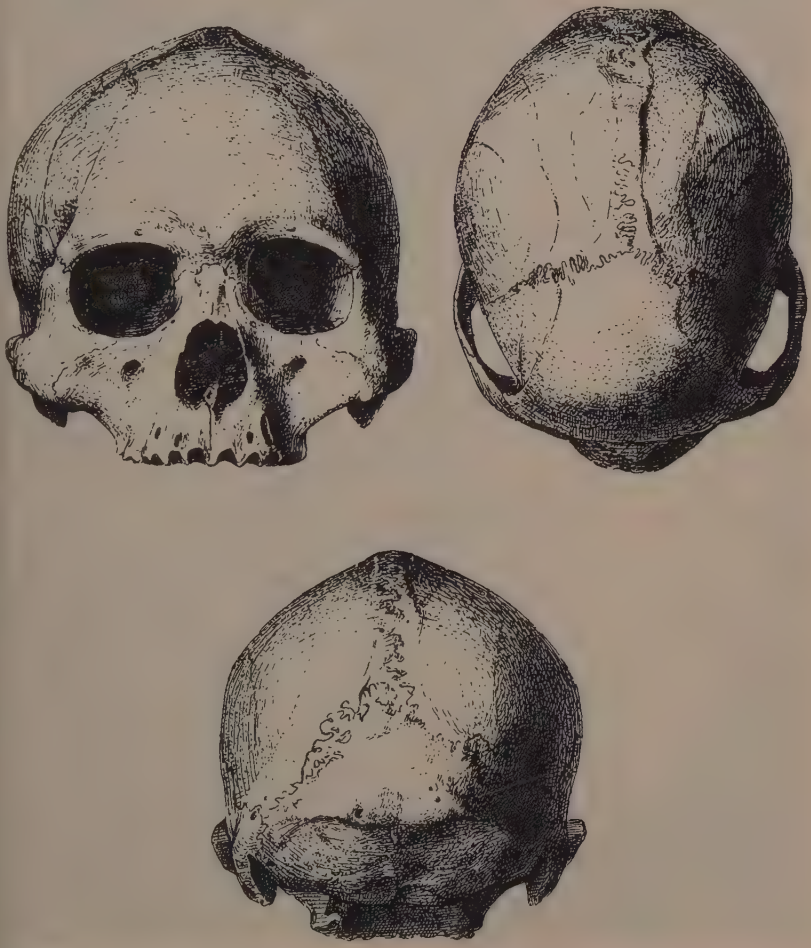
In a recent paper on Correlation of Change in the Evolution of Higher Primates, Zuckerman ('54, 317) expresses the opinion "that the Australopithecine head was carried as it is in a quasi-quadrupedal animal, such as the gorilla and chimpanzee, or as in those deities of the Ancient Egyptians, whose bodies were human but whose heads were animal." One of the reasons for his opinion is the fact that the two skulls of *Paranthropus crassidens*, regarded as female, possess sagittal crests, which, in Zuckerman's view, leads to the conclusion that they must also have had an occipital crest and an ape-like planum nuchale. Although the occipital region of both skulls is lacking, Broom and Robinson ('50, 56 f.) assumed that the sagittal crest in these two adult skulls did not extend backwards to a confluence of sagittal and occipital crests, because a crest was not obvious on the occipital of an adolescent skull, also assigned to *Paranthropus.* Zuckerman objects to this conclusion on the ground that "an immature skull would not be expected to be furnished with such a crest," which is certainly sound criticism. In order to establish his postulate that a sagittal crest always implies the presence of an occipital crest, he and Mr. R. J. S. Savage examined a large number of primate and other mammalian skulls and found that in all cases a sagittal crest is associated with an occipital crest. Only in a specimen of *Nycticebus* and some skulls of the hollow-faced bat, *Nycterus,* did a well developed sagittal crest go together with a poorly developed nuchal crest. And Zuckerman ('54, 328) concludes that "unless *Paranthropus crassidens* is the one exception to a morphogenetic process common to all Primates, it follows that its possession of a high sagittal crest presupposes the presence of a powerful and shelf-like occipital torus."

This seems to be a well-founded argument indeed. But it overlooks the remarkable degree of variability in the position of the temporal lines that can be found in recent man. I should like to call attention in this paper to a certain number of recent human skulls in which the two temporal lines come very close together and also show that, if all the facts determining the position of the temporal lines on the skull are taken into consideration, recent man falls well within the range of variation of non-human primates.

MATERIALS AND METHODS

Without giving exact measurements, many authors have noticed the high position of the temporal lines in such groups as the Eskimos, Australians, Melanesians, certain groups of the American Indians, and others. (Summary in Matiegka, '06, 365 f, and bibliography.) The easiest way to describe the position of the two temporal lines is by measuring the minimum distance between them in the area of the sagittal suture. The following cases have been described in the literature: An Eskimo skull from Smith Sound has an intertemporal distance of 60 mm; in a few Eskimo crania from Southampton Island, the distance is 67 mm, 68 mm, 74 mm, 77 mm, 79 mm, and more (Hrdlicka, '10, 198 f.); in a Greenland Eskimo skull it is 65 mm, narrowing down to 30 mm near lambda (Matiegka, '06, 357); in a New Caledonian skull it is 53 mm, and in a skull from Vancouver it is 52 mm (Matiegka, '06, 358, after Topinard and Corner). In skulls of different provenience (Chinese, Tagals, Madurese, Kurds, and others) mentioned by Hyrtl (1872, 43 f.) the intertemporal distance ranges between 50 and 67 mm and more, in a French skull it is 40 mm, and in a possibly Austrian skull it is only

12 mm. (Le Double, '03, 128, who quotes this case from Zuckerkandl, 1875, 109, says that it is an Austrian skull, but in Zuckerkandl's original report there is no reference to the provenience of this skull.) Virchow (1892, Pl. XVI, figs. 1, 2, 4, and accompanying text) has described and figured a Paiute skull, in which the minimum distance is 10 mm, and the Amer. Mus. of Natural History has an Eskimo skull from



Figs. 1, 2, 3 Paiute skull with very high temporal lines, minimum intertemporal distance 10 mm. (After Virchow, 1892, Pl. XVI. figs. 1, 2, 4.)

Smith Sound (no. 99/108), in which it is only 7 mm . This skull has also been described and figured by Hrdlicka ('10, 259, Pl. XX). Apart from this latter truly remarkable case, I wish to put on record 66 other skulls in the collections of

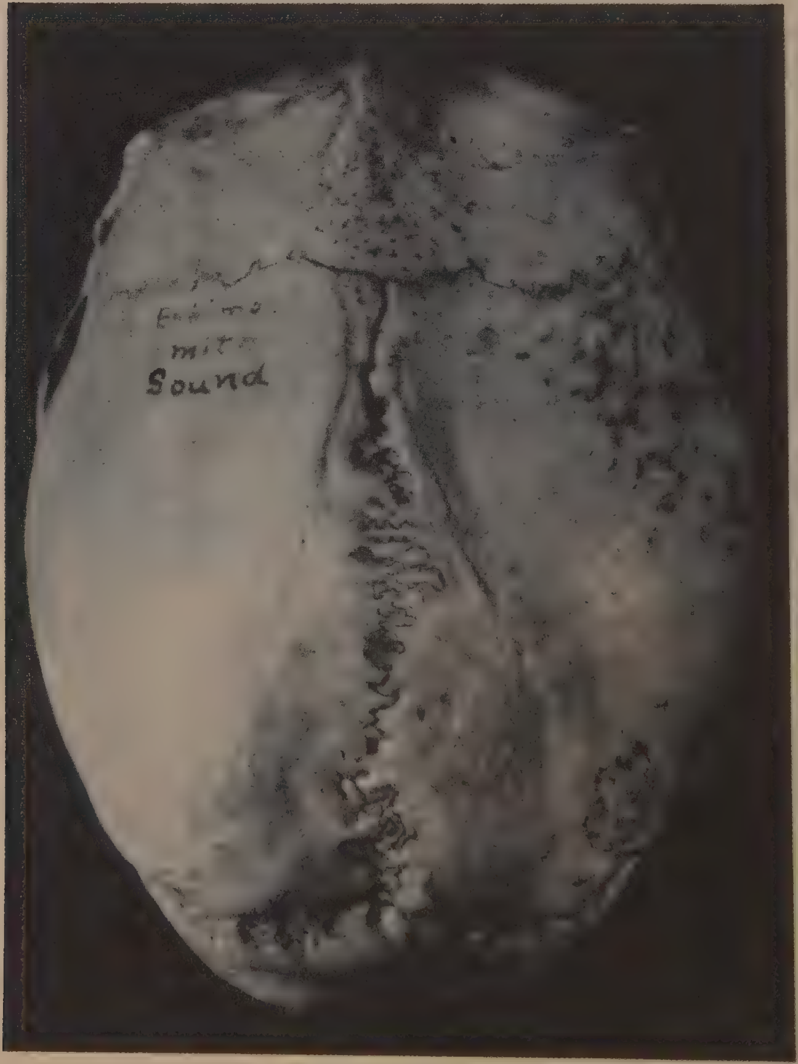


Fig. 4 Eskimo skull from Smith Sound, minimum intertemporal distance 7 mm Amer. Mus. of Natural History no. 99/108.

the American Museum, in which the two temporal lines approach each other very closely. These skulls represent the result of a careful examination of several thousand skulls in the American Museum. Since Eskimos, Melanesians, Australians, and a few others figure prominently in this selected sample, our findings confirm those of previous observers who have found these groups to be outstanding in the development of their planum temporale. In none of these cases do the nuchal lines differ in any way from those in ordinary skulls with strong occipital muscle markings. The observations made on these skulls are contained in table 1.

RESULTS

In order to show that the above minimum distances between the temporal lines in various human groups fall well within the range of primate variation, two female gorillas, two female orangs, 12 male and 6 female chimpanzees, as well as 19 male and 14 female gibbon skulls (*Hylobates hoolock*) were selected for comparison. The sample is selective in the sense that specimens with a sagittal crest were eliminated, but all specimens represent adults with fully erupted dentition and achieved closure of the sutures, so that the position of the temporal lines can be considered as final. The observations made on this sample are contained in table 2. No averages have been computed for the minimum intertemporal distance since the values are selective, but the range of variation is immediately visible from the data. Since, on the other hand, the hylobates material is not selective, averages have been computed.

It appears from these data that the smallest intertemporal distance in our small selected sample is that of a female gorilla in which it is 8 mm, and that the widest separation of the lines appears in a male chimpanzee, in which it is 52 mm. This shows that many values of our selected human sample fall well within the range of this variation; the intertemporal distance of 7 mm in the Eskimo skull from Smith Sound is even smaller than that of the female gorilla.

TABLE 1

TRIBE AND CATALOGUE NO.		MINIMUM DISTANCE BETWEEN 2 TEMPORAL LINES (a)	TRANSVERSE ARC (b)	$\frac{a \times 100}{b}$	LENGTH OF PLANUM TEMPORALE (c)	MAXIM. LENGTH OF SKULL (d)	$\frac{c \times 100}{d}$	MAXIM. WIDTH OF SKULL	CEPHALIC INDEX	THICKENING ALONG SAGITTAL SUTURE
Eskimo (Ponds Inlet)										
99/6687	♂	51	290	17.59	168	183	91.80	139	75.96	med.
Eskimo (Pt. Hope)										
99.1/668	♂	46	295	15.59	. . .	174	. .	139	79.89	slight
Eskimo (St. Lawrence I.)										
99/3719	♂	56	310	18.06	175	188	93.09	140	74.47	marked
Eskimo (Southampton I.)										
99/4661	♂	65	293	22.18	160	201	79.60	141	70.15	slight to med.
99/4662	♂	74	300	24.66	153	190	80.53	138	72.63	slight to med.
Eskimo (Smith Sound)										
99/105	♂	47	315	14.92	169	190	88.95	148	77.89	slight
99/108	♂	7	303	2.31	176	191	92.15	140	73.30	marked
99/7688	♂	63	305	20.65	167	184	90.76	141	76.63	slight
99/7689	♂	67	303	22.11	163	183	89.07	140	76.50	slight
Eskimo (Greenland)										
99/3790	♂	63	303	20.79	170	188	90.43	149	79.26	marked
99/4102	♂	69	290	23.79	160	186	86.02	136	73.12	slight to med.
99/7699	♂	67	305	21.97	170	195	87.18	139	71.28	slight
99/8910	♂	65	305	21.31	162	189	85.71	140	74.07	slight
99/8911	♂	55	293	18.77	163	190	85.79	138	72.63	med.
Eskimo										
99/3643	♂	51	277	18.41	151	190	79.47	136	71.58	slight
Eskimo										
99/3849	♂	65	290	22.41	165	188	87.77	139	73.94	none
Eskimo,	16 ♂									
Average:			298.56	19.09	164.80	188.12	87.22	140.19	74.58	
Ralum										
1206	♂	55	265	20.75	155	177	87.57	126	71.19	marked

1615	♂	47	280	16.78	155	172	90.12	126	73.26	med.
1627	♂	55	292	18.83	156	183	85.25	131	71.58	slight to med.
1629	♂	64	294	21.77	154	186	82.80	132	70.97	slight
1632	♂	61	299	20.40	165	188	87.77	132	70.21	med.
1633	♂	70	297	23.57	147	184	79.89	136	73.91	none
1638	♂	69	314	21.97	176	190	92.63	134	70.53	slight
1640	♂	59	294	20.07	149	185	80.54	129	69.73	none to very slight
1645	♂	45	300	15	162	190	85.26	130	68.42	med. to marked
1656	♂	34	299	11.37	180	190	94.74	126	66.32	marked
2836	♂	64	275	23.27	136	174	78.16	121	69.54	slight
2850	♂	66	291	22.68	159	191	83.25	131	68.59	slight
4651	♂	57	289	19.72	156	186	83.87	134	72.04	slight
4655	♂	59	285	20.70	151	179	84.36	130	72.63	marked
4656	♂	66	291	22.68	167	190	87.89	140	73.68	none to very slight
Ralum	20 ♂									
Average:		..	290.15	20.40	159.30	184.65	86.24	129.70	70.26	
Ralum										
1570	♀	65	282	23.05	157	177	88.70	130	73.45	none to very slight
2035	♀	60	279	21.50	...	176	..	127	72.16	none
Baining										
4732	♂	63	289	21.80	155	176	88.07	127	72.16	slight
99/8233	♂	66	309	21.36	157	185	84.86	128	69.19	practically none
99/8234	♂	67	305	21.97	168	179	93.85	140	78.2	none
99/8236	♂	58	300	19.33	171	188	90.96	136	72.34	med.
Baining										
99/8241	♀	44	314	14.01	180	192	94.24	138	71.88	slight to none
New Ireland										
1116	♂	46	281	16.37	171	178	96.07	125	70.22	slight
99/71	♀	61	299	20.40	172	177	97.18	136	76.84	med.
Solomon Islands										
99/9645	♀	70	301	23.25	156	176	88.64	134	76.14	none
Abgarris (Fead) Island										
634	♂	64	285	22.46	160	178	89.89	127	71.35	slight
New Zealand										
99/6562	♂	68	304	22.37	167	187	89.30	128	68.45	med.
Marquesas Islands										

TABLE 1 *(continued)*

TRIBE AND CATALOGUE NO.		MINIMUM DISTANCE BETWEEN 2 TEMPORAL LINES (a)	TRANSVERSE ARC (b)	$\frac{a \times 100}{b}$	LENGTH OF PLANUM TEMPORALE (c)	MAXIM. LENGTH OF SKULL (d)	$\frac{c \times 100}{d}$	MAXIM. WIDTH OF SKULL	CEPHALIC INDEX	THICKENING ALONG SAGITTAL SUTURE
Australia										
244	♂	71	265	26.80	138	172	80.23	119	69.19	slight to med.
99/67	♂	51	300	17	180	180	100	132	73.33	med. to marked
99/8217	♂	58	277.	20.94	152	183	83.06	121	66.12	marked
99/8171	♀	72	294	24.49	141	183	77.05	125	68.31	none
China										
1728	♂?	56	283	19.79	167	175	95.43	138	78.86	slight
1736	♀?	37	293	12.63	176	176	100	139	78.98	slight to med.
Japan										
4675	♂	66	286	23.08	153	176	86.93	134	76.14	slight
Malayan (Singapore)										
3390	♂	41	304	13.49	176	168	104.76	145	86.31	slight
3393	♂	44	309	14.24	172	169	101.78	141	83.43	med. to marked
3393	♀	39	281	13.88	158	161	98.14	138	85.71	slight to med.
Siam										
2441	♂	59	294	20.07	153	169	90.53	142	84.02	slight
Kalmuk										
4769	♂	59	296	19.93	145	186	77.96	146	78.49	med.
British Columbia										
99/1716	♂	45	304	14.80	175	179	97.77	138	77.09	med.
Utah										
99/7364	♂	74	294	25.17	175	185	94.59	133	71.89	marked
Ona										
99/6593	♂	51	305	16.72	182	200	91	141	70.50	slight
Chile (Punta Pichalo)										
99/749	♂	30	291	10.31	151	182	82.97	133	73.08	marked
Venezuela (Altapacia)										
620	♂	39	275	14.18	151	178	84.83	132	74.16	marked
Austria										
1345	♂	70	314	22.29	158	177	89.27	148	83.62	med.

TABLE 2

CATALOGUE NO.		MINIMUM DISTANCE BETWEEN 2 TEMPORAL LINES (a)	TRANSVERSE ARC (b)	$\frac{a \times 100}{b}$	LENGTH OF PLANUM TEMPORALE (c)	MAXIM. LENGTH OF SKULL (d)	$\frac{c \times 100}{d}$
Gorilla							
L 20	♀	8	197	4.06	139	145	95.86
Gorilla							
99/9688	♀	17	202	8.41	142	151	94.04
Chimpanzee							
L 281	♂	16	181	8.60	122	126	96.83
L 18	♂	12	187	6.42	126	130	96.92
L 269	♂	16	198	8.08	126	137	91.97
L 247	♂	11	200	5.50	136	148	91.89
L 207	♂	22	180	12.22	125	occipital missing	....
L 22	♂	39	208	18.75	123	141	87.23
L 209	♂	16	177	9.04	120	occipital missing	....
51202	♂	24	202	11.88	130	136	95.59
51203	♂	13	195	6.67	130	139	93.53
51207	♂	52	210	24.76	124	144	86.11
51379	♂	34	191	17.80	118	131	90.08
51381	♂	25	194	12.89	128	131	97.71
Average:	♂	..	193.58	11.88	125.67	136.30	92.79
Chimpanzee							
5	♀	31	170	18.23	116	130	89.23
L 15	♀	9	172	5.23	113	128	88.28
L 210	♀	10	170	5.88	115	126	91.27
L 212	♀	34	166	20.48	117	126	92.86
L 261	♀	51	200	25.50	113	144	78.47
90264	♀	22	184	11.96	115	131	87.79
Average:	♀	..	177	14.55	114.83	130.83	87.98
Orang							
L 23	♀	15	207	7.25	126	130	96.92
L 246	♀	18	179	10.05	100	117	85.47
Hylobates hoolock							
19 ♂ Average:		22.10	127.63	17.30	66.89	84.10	80.74
14 ♀ Average:		21.28	126.10	16.86	66.07	84.28	78.40

However, a mere comparison of absolute intertemporal distances represents a somewhat simplified picture of the true situation, and other facts have to be taken into consideration. For the development of the temporal muscles and the relative extension of the planum temporale depend not only on the heaviness of the mandible, but also on the surface area available for the insertion of the temporal muscles. A study of this kind should actually include comparative data on the heaviness of the mandibles, but the material is not available in a sufficient number of cases. The surface area available for the insertion of the temporal muscles is best expressed by the transverse arc. This measurement was taken from the sharp ridge on the upper part of the transverse root of the zygoma (as by Corner, 1896, 378, and not from porion, since this corresponds better to the lower limits of the muscles) over vertex (not over bregma, as by Hrdlicka, '10, 198, since bregma is not clearly visible in most of the primate skulls). The fact that in cases of average mandibular development the position of the temporal lines depends on the size of the skull and, consequently, on the insertion area available for the temporal muscles, is best demonstrated by reference to microcephalic skulls in which, because of the reduction of the insertion surface on the parietals, the temporal lines move very high up on the skull. Thus the intertemporal distance in a number of microcephalic skulls mentioned in the literature is: 52 mm, 50 mm, 46 mm, 44 mm, 38 mm, 30 mm, 22 mm, and 10 mm (Le Double, '03, 127, and bibliography). Vogt (1876, 150) mentions a male microcephalic skull, in which the distance is only 5 mm, and Costa Ferreira ('20, 1195 f.) reports the case of a female microcephalic skull, in which coalescence of the temporal lines occurs near bregma. Similarly, Joseph (1876, 523 f.) has pointed out that the higher position of the two temporal lines in primates is due not only to the greater heaviness of the lower jaw but also to the smaller size of the skull. This relationship is confirmed by a smaller intertemporal distance in lower human skulls if compared with high skulls of equal mandibular development (Matiegka, '06, 381 f.) and by pathologically enlarged macrocephalic skulls, in which the temporal lines are extremely wide apart. Thus, a macrocephalic skull in the American Museum (no. 3326, see table 1) with the remarkable transverse arc of 348 mm, has a minimum intertemporal distance of 144 mm. That the transverse arc in our primate material is much smaller in its individual values as well as in its averages than the human material is immediately evident from the above data. The average index $\frac{\text{Minim. intertemporal distance}}{\text{Transverse arc}} \times 100$ on the other hand is smaller in all primates than in the human material because of the smaller average intertemporal distance in the primates. But here again, if the range of variation of the indices in our primate sample from 4.06 in the female gorilla to 25.50 in the female chimpanzee is kept in mind, it appears that all human skulls of our sample fall within this range of primate variation, that the index of the Eskimo from Smith Sound with a value of 2.31 is even smaller than that in the female gorilla, and that only one Australian skull (no. 244) with an index of 26.80 falls outside the range of variation of our primate sample. However it must not be overlooked that with its intertemporal distance of 71 mm this skull is clearly at the upper border of our sample and could legitimately be eliminated from a selective sample emphasizing the narrow distance between the temporal lines. If, therefore, it is kept in mind that in spite of the greater heaviness of the mandible and smaller transverse arc in primates, a selected human sample falls within the range of primate variation not only in regard to the absolute but also the relative intertemporal distance, it follows that an oversimplified emphasis of the differences between human and primate development of the plana temporalia is an erroneous conception; and it appears clearly that both, human and anthropoids, are characterized by an extreme variability of the position of the temporal lines. Or, expressed differently, if in spite of his lighter jaw and the larger insertion area for the temporal muscles, the temporal lines in man can move up so high as almost to meet in the median line, the appearance of a sagittal crest in *Australopithecus crassidens* loses a great deal of its specific quality and would seem to be only the extreme expression of this principle of variability. Since in man, an intertemporal distance absolutely and relatively smaller than in apes does not imply a deviation from the usual carriage of the head, a small intertemporal distance with its extreme expression in the form of a sagittal crest would seem to have only very doubtful diagnostic value for postulating such a feature. Although it is true that an occipital crest is present in all animals includng primates in which a sagittal crest occurs, this observation is made on animals in which the foramen magnum is more backwardly located, implying a more unfavorable head-balancing situation and consequently a greater need for strong muscular development in the nuchal area. It is doubtful whether such an observation can be applied to the australopithecines in which the foramen magnum is more central, even though the magnitude of the difference in its position is a matter of controversy. Moreover, if it is kept in mind that the carriage of the head is the same in all living anthropoids in spite of the fact that a shelf-like occipital crest is present in some but absent in others, it becomes equally questionable whether an occipital crest has any diagnostic value in regard to the carriage of the head. The position of the foramen magnum would therefore seem to be related to the way in which the head is carried. Zuckerman does not fully subscribe to such a view, since in young primates the foramen magnum is forwardly located without implying a posture and carriage of the head different from that in the adult animal. Intriguing as this argument may be, it is exactly this same logic which deprives the sagittal and occipital crests of their diagnostic value.

While there is a certain overlapping between our human and primate sample in regard to the absolute and relative intertemporal distance, the absolute and relative differences are somewhat more accentuated in regard to the length of the planum temporale. The length of the planum was measured with tape in order to take into consideration the depth of the postorbital constriction and the bulging of the parietals. The absolute length of the planum is of course smaller in most cases in the non-human primates due to the smaller size of the skull, but its relative length (compared with the maximum length of the skull) is generally greater. But here too, there are overlapping individual cases in the absolute and relative sense.

Skull shape in relation to temporal muscle

If the above material (table 1) is viewed with regard to the shape of the skull, it appears that very high temporal lines and thus strongly developed temporal muscles occur in dolichocephalics (Eskimos, Melanesians, Australians, and others), mesocephalics (Chinese, Japanese, Kalmuk, and a skull from British Columbia), and brachycephalics (Malayans, one Siamese, and one Austrian). To this could probably be added the skull mentioned by Zuckerkandl if Le Double's remark is substantiated that it was that of an Austrian; for in that case it is very likely to have been brachycephalic although Zuckerkandl does not say anything on this subject. In the two Malayan skulls the index is even hyperbrachycephalic. This shows that the shape of the skull and the action of the temporal muscles are independent from each other, as has been demonstrated experimentally by Washburn ('47), and as is also to be expected from the fact that the full development of the human temporal muscles is reached long after the shape of the skull has been definitely formed. It is surprising that in the long discussion preceding Washburn's experimental demonstration it did not occur to anybody to call attention to an experiment carried out by nature itself and clearly showing the lack of relationship between the shape of the skull and the development of the temporal muscles. Since in microcephalic skulls the planum temporale moves up very high on the skull, one should expect microcephalic skulls to be generally dolichocephalic if the temporal muscles exerted any lateral compression determining the shape of the skull. Vogt (1867) in his study of microcephalic adult skulls repeatedly emphasizes the high position of the temporal lines and gives a certain number of intertemporal distances. If these distances are juxtaposed with the cephalic indices of the skulls as given by Vogt or computed from his measurements (see Vogt, 1867, 166, 171), the following appears:

INTERTEMPORAL DISTANCE	CEPHALIC INDEX
5 mm	85.
10 mm	75.
20 mm	77.
30 mm	76.
44 mm	84.
50 mm	82.

Moreover, in other microcephalic skulls studied by Vogt, in which the intertemporal distance is not given, the cephalic index is: 85., 86., and 87. Since this represents a range from dolichocephaly to hyperbrachycephaly, it is obvious that the development of the muscles has no effect on the shape of the skull. It is particularly interesting to see that the skull with an intertemporal distance of only 5 mm has a cephalic index of 85. It might be added that the form of these skulls is in no way the result of a premature closure of the sutures, for, as Vogt has emphasized clearly, the sutures are open in most cases. Nor is the thickness of the bones any greater than in normal skulls (Vogt, 1867, 196) thus depriving the obsolete theory of its argument that the thickness of the bones might have prevented a lateral compression by the muscles.

On the other hand it appears clearly that in our selected sample high temporal lines are much more frequent in dolichocephalic than in brachycephalic skulls. Hyrtl (1872, 40), Corner (1896, 379 f.), and Matiegka ('06, 356) have already pointed out that in narrow skulls the upper temporal lines move closer together, whereas in broad skulls they are further apart. This would seem to contradict the above statement of the independence of the development of cranial form from the action of the muscles and would seem to favor the view that the shape of the skull depends on the degree of lateral pressure exerted by the temporal muscles. However, the relationship between the shape of the skull and the position of the temporal lines must be interpreted on entirely different grounds. First, the dolichocephalic skulls here mentioned are all characterized by a heavy jaw, implying a strong development of the temporal muscles, and, secondly, dolichocephalic skulls of identical or even greater basion-bregma height have a smaller transverse arc than brachycephalic skulls. This is due not only to the smaller width of the skull but also to the fact that the planum is flatter in dolichocephalics and more bulging in brachycephalics. Thus dolichocephalics provide a more reduced surface area for the insertion of the temporal muscles and parallel the situation previously mentioned in microcephalics versus macrocephalics. While the average value for the transverse arc in the males of our Eskimo sample is 298.65 mm, and 290.15 mm in the males of our Melanesian (Ralum) sample, a test sample of 100 Austrian brachycephalic skulls (see table 3) with an average cephalic index of 84.84 for 67 male skulls and 85.58 for 33 female skulls gives an average transverse arc of 318.46 mm for the males and 309.91 mm for the females. But individually there appear such values as 340 mm, 341 mm, and

TABLE 3

RIANS rages	MINIMUM DISTANCE BETWEEN 2 TEMPORAL LINES (a)	RANGE OF VARIATION OF (a)	TRANSVERSE ARC (b)	$\frac{a \times 100}{b}$	LENGTH OF PLANUM TEMPORALE (c)	RANGE OF VARIATION OF (c)	MAXIM. LENGTH OF SKULL (d)	$\frac{c \times 100}{d}$	MAXIM. WIDTH OF SKULL	CEPHALIC INDEX
f lls	40	40	67	40	38	38	67	38	67	67
ians: les	109.70	70–136	318.46	34.54	142.34	111–167	176.13	80.72	149.28	84.84
f lls	6	6	33	6	6	6	33	6	33	33
ians: ales	112	93–123	309.91	36.31	123.33	106–145	169.94	71.28	145.27	85.58

353 mm for the transverse arc in male skulls, so that it approaches very closely or even exceeds the transverse arc of a macrocephalic skull, in which this arc measures 348 mm. (For a comparative table of the transverse arc in different racial groups, see Martin ('28, 760). Most of these values are slightly higher, since most authors take this measurement from porion.) Concomitantly, the intertemporal distance is greatly increased in the Austrian skulls giving an average of 109.70 mm for 40 males and of 112. mm for 6 females with a range of variation of 70–136 mm for the males and 93–123 mm for the females. Thus the upper male values approach again the macrocephalic condition in which the intertemporal distance is 144 mm in one observed case. The low position of the temporal lines in the Austrian sample ties in also with a relative lightness of the mandible. At the same time the temporal lines are so faintly marked that out of 100 skulls the intertemporal distance could be clearly established only in the above mentioned 46 skulls. This percentage is, however, slightly vitiated by the fact that the surface conditions of the bone are partly damaged which adds to the invisibility of the temporal lines.

A brief and incomplete check of the literature on the intertemporal distance in early man reveals the following information. Referring to *Pithecanthropus* and *Sinanthropus,* Weidenreich ('43, 160) says that the temporal lines "run a good deal farther laterally and below the midline and median crest"; and in regard to *Pithecanthropus* IV he mentions that the temporal lines cannot be traced on account of the crushed conditions of the parietals. In *Pithecanthropus* I, the minimum intertemporal distance is 85 mm, which is a relatively large distance in view of the small size of the skull. In Neanderthal Man the intertemporal distance is even larger giving 125 mm for Spy no. 2, 128 mm for the Neanderthal specimen, 130 mm for the skull of La Chapelle-aux-Saints, but only 89 mm for the Rhodesian skull. In the adult Gibraltar skull "the lines of attachment of the temporal muscles and fascia were about as in modern skulls." (Hrdlicka, '30, 51, 125, 166, 187; Martin, '28, 722.) It is conceivable that in Neanderthal Man the large intertemporal distance is brought about by the rather large transverse arc. This arc, if measured on the cast, gives approximately 312 mm for the skull of La Chapelle-aux-Saints and 305 mm for that of La Ferrassie. However, a detailed study of this subject would have to use the original finds.

The torus parietalis

Finally, I should like to call attention to a thickening along the sagittal suture, since its formation seems to be related to the development of the temporal muscles. Waldeyer (1893, 113 f.), who has discussed this feature, distinguishes between a *torus parietalis medialis* and a *torus parietalis lateralis*. In *medialis,* the thickening is found in the area of the sagittal suture, in *lateralis* the sagittal suture is caved in and two lateral ridges run along this groove. Although a distinction between these two morphological types is not important for our purposes, its terminology is given here in order to clear up the uncertainties that exist with regard to the terms applied by various authors to this area of the skull. The torus parietalis, which in its appearance is reminiscent of the torus palatinus, is not identical with the sagittal torus (scaphocephaly of most authors, the ''crest'' of others, and Sergi's lophocephaly), since it occurs in cases with and without a sagittal torus. But it has this in common with the sagittal torus, that neither of them has anything to do with the sagittal crest of certain anthropoids. For while the latter gives insertion to the temporal muscles and thus corresponds to the temporal lines, the sagittal and parietal tori do not. In regard to the sagittal torus, this fact has clearly been pointed out by Matiegka ('06, 379 f.), Hrdlicka ('10, 195), and Weidenreich ('43, 160, 194 f.), the latter considering it as part of a general reinforcement system of the skull. But in spite of this obvious functional difference between the parietal torus and the sagittal crest, it seems likely that the development of a parietal torus is the result of a strong development of the temporal muscles. This follows from the observation indicated in the above table 1 showing that out of 67 skulls of various racial provenience with a very high position of the temporal lines, the parietal torus is slight in 22 cases, slight to medium in 7 cases, medium in 3 cases, medium to marked in 3 cases, and marked in 10 cases. To this we can add the Paiute skull mentioned by Virchow, which, according to Virchow's detailed description and figure is characterized not only by a very narrow intertemporal distance (10 mm), but also by a marked parietal torus. On the other hand, 7 skulls in this sample show no parietal torus at all, one has practically none, and in 5 it is none to slight. Even if we pool these latter cases and consider all of them as having no parietal torus at all, we get only 13 cases in the total sample of 68. This means that at least 80.88% of the skulls with strong development of the temporal muscles show a parietal torus ranging from slight to marked. And although the relationship between the degree of the parietal torus and the intertemporal distance in individual cases is not a rigid one, it still appears from the above data that, with few exceptions, the cases without a parietal torus are also those within our sample in which the intertemporal distance is generally greater, i.e., in which the temporal muscles are less expanded. Thus the average intertemporal distance in the skulls of both sexes without a parietal torus is 64.61 mm against only 55.82 mm in those which have a torus. The same appears even more clearly when the sexes are separated, for in the 8 male skulls without a torus the average distance is 66.12 mm but only 56.50 mm in the 52 male skulls with a torus; and, similarly, in the 5 female skulls without a torus it is 62.20 mm, but only 45.67 mm in the 3 skulls with the torus.

Such a relationship between the development of the temporal muscles and the quality of the sagittal suture is not unusual in view of the fact that Washburn ('47) has shown experimentally that in those cases in which the temporal muscles of rats were cut, the sutures develop a very simple pattern. It would seem that the relationship between the development of a parietal torus and that of the temporal muscles is in fact of a similar order, and that a parietal torus develops as a response to the stimulus of an increased pull of the temporal muscles. Moreover, if it is kept in mind that in the entire sample of 68 skulls with high temporal lines containing 60 males and 8 females, 8 males and 5 females are without a torus, this means that it is absent in only 10.33% of the male skulls but in 62.5% of the female skulls with high temporal lines. Thus, if the assumed connection between the temporal muscles and the parietal torus is correct, the greater absence of a parietal torus in females would parallel that of a weaker development of muscle markings in females.

The validity of the hypothesis of a connection between the parietal torus and the development of the temporal muscles can be checked in two different ways: first, by the experimental method, and secondly, by the comparative method. An experiment could proceed by using a hard diet for young animals thus stimulating the development of the temporal muscles. In view of the remarkable differences in biting pressure observed in children brought up on different diets (see Heath, '48) such an approach seems to be most promising. It might, at the same time, provide an answer to the problem of the sagittal torus, for the formation of which a variety of reasons have been suggested. On comparative grounds, the easiest check to find out whether a parietal torus develops as a result of a relatively close approach of the temporal lines consists in taking a sample of skulls in which the temporal lines are far apart. Since such a condition occurs in brachychephalic skulls, the 100 skulls of our brachycephalic Austrian sample were checked with regard to the presence of a parietal torus. It appears that out of 67 male skulls, 12 show a parietal torus ranging from very slight to medium (two very slight, 4 slight, two slight to medium, 4 medium); and out of 33 female skulls, only two show a parietal torus of very slight development. This gives a frequency of 14% for the entire sample against 80.88% in our selected sample with very high temporal lines. On the other hand, the average intertemporal distance in the Austrian males with a parietal torus is 95.91 mm against an average of 114.93 mm in the remaining 29 males without torus, in which the distance can be measured. In the two females with very slight parietal torus, the intertemporal distance cannot be measured in one case because of the weak marking of the temporal lines, and in the other specimen the distance is 93 mm, which is the smallest distance of all the females of the sample; and the average intertemporal distance in the 5 female skulls without a torus in which the distance can be measured is 115.80 mm. Thus, here again, although the relationship in individual cases is not a rigid one, the averages clearly indicate that, within the same group, those skulls with a smaller intertemporal distance develop a parietal torus more frequently than those with a larger intertemporal distance. This observation is borne out by the single macrocephalic skull and a certain number of adolescent skulls in which the temporal lines are relatively low. For in none of these cases is there any trace of a parietal torus. And in the Austrian sample it appears again that the parietal torus is rarer in females than in males (93.94% without torus in females and 82.10% without torus in males).

SUMMARY

In the present study, an analysis has been made of a sample of 68 human skulls of different racial provenience in which the temporal lines come very close together, so that in extreme examples they almost touch each other. It appears that the intertemporal distance in such a selected sample falls well within the range of variation of a primate sample from which cases with a sagittal crest have been eliminated. This fact and the fact that in cases of extreme approach of the temporal lines in recent man no deviation from the usual muscle markings can be recognized in the occipital area,

should be kept in mind in the interpretation of the isolated occurrence of a sagittal crest in *Australopithecus crassidens.* While it is fully recognized that the final answer to the question of the presence or absence of an occipital crest in *Australopithecus crassidens* will only be given when a complete adult skull or occipital of this type is found, the diagnostic value of an occipital crest for the carriage of the head seems doubtful, and the position of the foramen magnum seems to be more pertinent to the problem.

A high position of the temporal lines is more frequent in dolichocephalic than in brachychephalic skulls. This does not mean that the dolichocephalic form of the skull is produced by a greater lateral pressure of the temporal muscles. Higher temporal lines are due to the more reduced insertion area for the temporal muscles in dolichocephalic skulls.

The development of a parietal torus is more frequent in cases with high temporal lines than in those with a greater intertemporal distance. It seems therefore that the parietal torus develops as a response to greater pull of the temporal muscles. This rélationship seems to be of a similar order as that which exists between the development of the temporal muscles and the complexity of the sagittal suture.

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A CATALOG OF THE AUSTRALOPITHECINE FOSSILS FOUND AT THE LIMEWORKS, MAKAPANSGAT

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The increasing number of *Australopithecus prometheus* fragments emerging from the Limeworks site at Makapansgat has been suggesting for some time past the wisdom of drawing up a detailed catalog of the relevant material. Up to the present it has been possible to keep track of the important items through the publications dedicated to their description. The recent generosity of the Wenner-Gren Foundation has enabled us to push forward the sorting of the dump and thus to recover so many more specimens that a full catalog can no longer be safely avoided. It is only right for his unsystematic collaborator to remark that, had Father E. Boné not shared in the field work of the 1955 season at Makapansgat and himself advocated the potential value to overseas students of this enumeration, its compilation would probably have been delayed indefinitely.

The catalog set forth here comprises all of those fragments unearthed up to the present time, including two dubious fragments (indicated as such) and also such adjacent pieces of breccia, as expand our information by natural casts or impressions of the australopithecine osseous or dental remains. All of the australopithecine fossils had been recovered from the basal grey breccia at Makapansgat until 30th April 1955 when Mr. Alun R. Hughes recovered a maxillary fragment from the pebble culture stratum of the great cone (48′ high and 111′ × 144′ at the base) that had fallen from the roof in the southern half of the cavern system.

A gravel bed in the northern face of the conical overhang exposed by the subsidence formed the horizon from which Mr. C. K. Brain recovered the Developed Kafuan pebble tools in October 1954. The first knowledge that it also is fossiliferous came on 29th April 1955 when Mr. Revil Mason found therein what appeared to be part of a giraffe mandible. To distinguish the australopithecine specimens from this important site, therefore, we are using the letters MLC as opposed to MLD for those coming from the Makapansgat Limeworks Dump.

It has been deemed advisable to use this triple lettering system also because the Makapansgat valley comprises not only the Limeworks, Cave of Hearths and Rainbow Cave sites but numerous other caves some of which (e.g. Buffalo Cave) have already yielded type specimens housed in the collections of the Bernard Price Institute for Palaeontological Research, and which may also yield in the future fossils of physical anthropological importance.

Every piece has been given in addition an ordinal number, corresponding very simply to the sequence of discovery: thus the maxillary fragment found at the Makapansgat Limeworks Cave site will be labelled MLC 1, the date of discovery of each specimen (in this case 30. 5. 55) being recorded in the second column of the catalogue. The same ordinal number followed by a small letter *a* (3–3a, 6–6a) has been given to those pieces of breccia which, whether discovered before or after the australopithecine fragment, have been found to have been associated immediately therewith as impressions or casts.

Bibliographic references to the original or principal articles describing, or referring to particular objects, are included when relevant. Certain pieces have never been described; others are the subjects of notes actually in the course of publication. One and all will henceforward be identified by the symbols indicated below.

As far as these details have already been assessed by previous study, we have recorded for each fragment its probable sex and age. The last column of the table has been employed for indicating the doubtful nature of two pieces included in

TABLE 1

Australopithecine remains from Makapansgat Limeworks

FRAGMENT	DATE DISCOVERY	DESCRIPTION	SEX	AGE	PARTICULAR
Calvaria	Sept. 1947	1948, *6* (3): 259	♀ (?)	adult	
Adolesc. mandible	27. 7. 1948	1948, *6* (4): 391	♂	± 12 yrs.	
Parietal fr.	Sept. 1948	undescribed — announced 1949, *7* (2): 187		infantile	belongs to 11?
Endocast of 3	Sept. 1948				
Left M3 isolated	Sept. 1948	1949, *7* (2): 203	♀ (?)	adult	belongs to 18
Right M2 isolated	Sept. 1948	1949, *7* (2): 201	♂	juven.	
Cranio-facial fr. ("1st palate")	Oct. 1948	1949, *7* (2): 187	♀	adult	
Breccia Impressions of 6a	Sept. 1948	1949, *7* (2): 187	♀	adult	
Left ilium	Nov. 1948	1949, *7* (3): 301		adolesc.	belongs to 2?
Right ischium	Nov. 1948	1949, *7* (3): 301		adolesc.	belongs to 2?
Premaxillo-maxillary fr. ("2nd palate")	Nov. 1948	1949, *7* (3): 335	♀ (?)	adult	
Breccia (cast of 9)	Nov. 1948	undescribed			
Biparieto-occipital fragment	Nov. 1948	Zeitschr. f. Morphol. u. Anthropol., 1955, in press.			
Part of infant maxilla	July 1949	undescribed		infantile	belongs to 3?
Right M3 isolated	Nov. 1949	undescribed			
Isolated upper C	Nov. 1949	undescribed			
Humeral shaft fr.	Nov. 1949	L'Anthropol., 1955 in press			suspicious
Dist. extr. Radius	Nov. 1949	L'Anthropol., 1955 in press			belongs to 16
Prox. extr. Radius	Nov. 1949	L'Anthropol., 1955 in press			belongs to 15
Head of femur	Nov. 1949	L'Anthropol., 1955 in press			suspicious
Adult mandible	29. 7. 1953	1954, *12* (3): 313	♀ (?)	adult	belongs to 4
Left M3 + mandibular fragment	21. 4. 1955	undescribed			
Acrom. extr. collar bone	27. 4. 1955	undescribed			
Rt. M1 and 2 maxillary fr.	30. 4. 1955	announced Nature (in press)	♂ (?)	adult	

otherwise stated publications appear in Am. J. Phys. Anthrop.

the catalog and also for indicating the actual or suspected association of various pieces that have been discovered separately.

We intend in future to utilize the symbols proposed here to designate the australopithecine fragments discovered at Makapansgat and hope that this catalog will assist all those who are interested in the Limeworks site to identify and assess more conveniently the nature of the fossil hominid material it has yielded.

THE SPECIAL FEATURES AND STATUS OF THE SALDANHA SKULL

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FIVE FIGURES

The Saldanha skull has no individual feature that is not found in one or other of the known human fossils, but it has an interesting combination of primitive characters that give it a distinctive position in the human pedigree. It is another example of the diversity of character which appears to pervade fossil man, and seems to indicate that the variation in type of modern man, such as is shown by the contrasting Australian and South African Bushman, has a much more fundamental basis and significance than is usually given to it.

In this short note several features of Saldanha man will be discussed and conclusions stated regarding his taxonomic position.

The most striking feature of the Saldanha skull is undoubtedly the great development of its brow-ridges. In their medial two-thirds they show the same general contour and massiveness as the Rhodesian torus. This part of the Saldanha torus is inflated to a considerable extent by big frontal sinuses, but the author has no comparative data for the Rhodesian skull.

The outer third of the Saldanha torus tapers definitely towards its outer end, whereas the Rhodesian buttress maintains its massiveness right out to the zygomatic suture. Keith ('25) considered that the special robustness of the outer end of the Rhodesian torus must have been for the attachment of the frontal part of a particularly powerful temporal muscle, such as would have been in keeping with his massive jaws and face.

The relative refinement of the outer part of the Saldanha torus might be regarded as an indication that the Saldanha skull had belonged to a female of the Rhodesian type, but there are no other special suggestions of femaleness in this skull, and sexual variation usually affects the ridges as a whole.

It seems to the author that the relative attenuation of the outer ends of the Saldanha torus is best interpreted as indicating that this skull had a different type of masticatory apparatus from that of the Rhodesian skull. For this view there is actual evidence from the mandibular fragment which suggests that the Saldanha jaw was typically Neanderthaloid in shape, and quite out of harmony with the Rhodesian skull. My view, then, is that where the Saldanha torus differs from that of the Rhodesian it is in a Neanderthal direction.

The author's interpretation of the differences between the brow-ridges and indeed of most of the differences between these two skulls may be expressed differently in terms of the general principle which seems to lie behind the presence, modification or absence of brow-ridges. It is known that in any race which shows brow-ridges, these are developed in the adult as secondary sexual characters of the male. Their presence can therefore be described as both a gerontomorphic and an andromorphic character, whereas their absence or diminution denotes a paedomorphic and gynomorphic condition. The interesting thing is that this developmental and sexual antithesis of ontogeny finds a wider expression in racial phylogeny. In the *Homo sapiens* group, for example, we have the great contrast between the Australian aboriginal with his well-developed brow-ridges and the South African Bushman who is practically devoid of such ridges. The former is therefore an example of a gerontomorphic and andromorphic race, whereas the latter is paedomorphic and gynomorphic.

The whole primate phylum abounds with examples of wha can thus be regarded as "male" and "female" types or races relative to one another. For the present argument, the author regards the Rhodesian skull as that of an archandromorph relative to which the Saldanha skull is to a degree a gynomorph in this and other respects.

It follows also from the principle outlined above that brow-ridges or their absence are only fortuitous specializations of different races in much the same way as there are horned and hornless breeds of cattle. They are not in themselves determinants of morphological status or the Australian and South African aboriginals could not both be classified as sapient.

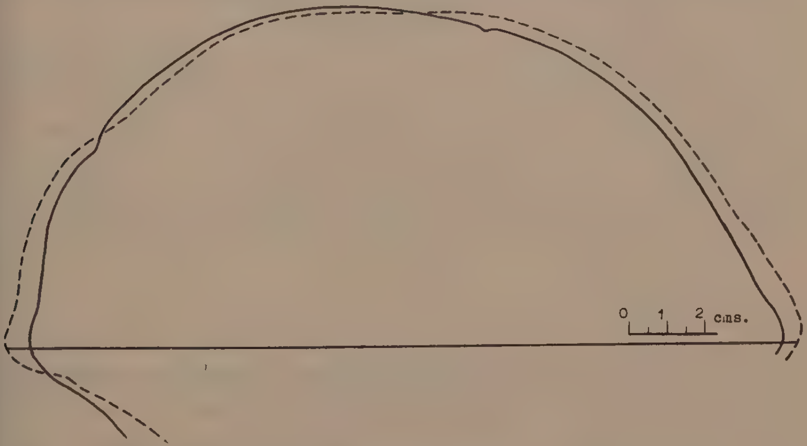

Fig. 1 Mid-sagittal contour of the Saldanha skull — continuous line, compared with that of a cast of the Rhodesian skull — broken line. These contours do not show the brow ridges.

No distinction can be drawn between the Saldanha and Rhodesian skulls in respect of the slope of the forehead (see fig. 1) which puts both into the Neanderthal category. The condition of the underlying frontal lobes of the brain, however, must have been decidedly different, because the frontal region of the Saldanha endocast has a much more primitive slope than that of the Rhodesian endocast (see fig. 2).

In the pre-bregmatic part of the frontal squama we encounter an important divergence in character. In this region the Rhodesian squama shows a vestigial median crest, and behind this there is a definite keeling of this skull (see fig. 3).

The Saldanha skull, on the other hand, shows no suggestion of these important features, being smoothly rounded from side to side, so that in this way it resembles the Neanderthals and the great majority of modern men. That this is a fundamental morphological difference has been clearly shown by Sergi ('30), who has traced simian and gerontomorphic keel-

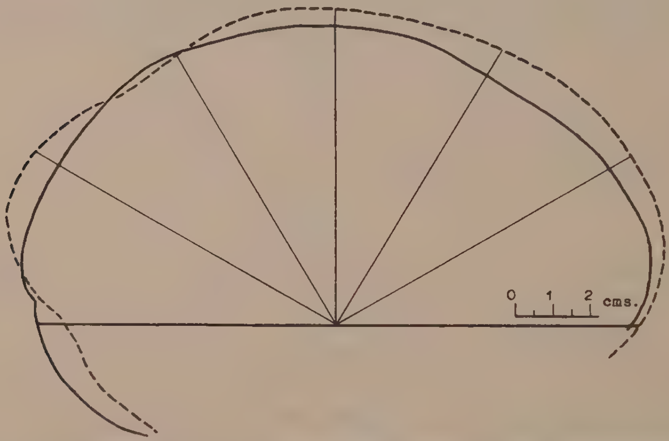

Fig. 2 Projection drawing of the sagittal contour of the Saldanha endocast — continuous line, compared with that of the Rhodesian endocast — broken line, after Weidenreich ('36).

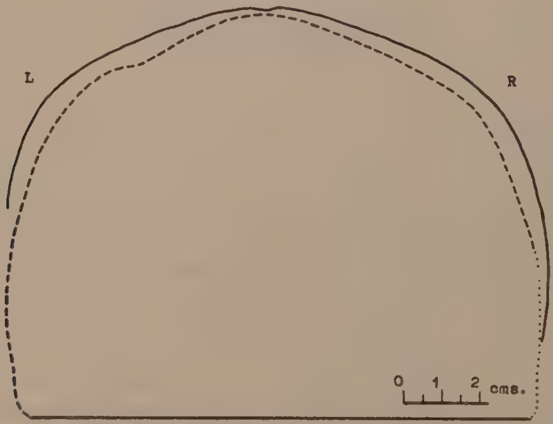

Fig. 3 Transverse contour through the vertex of the Saldanha endocast — continuous line, compared with that of the Rhodesian endocast — broken line, a shown by Morant's ('28) standard drawing.

ing or cresting of the skull from the Rhodesian to the Australian type, and he has given many examples of its distribution in Africa, Europe, Oceania and among early Americans. It is quite clear, however, that from an early stage in human development this archaic type of skull has been giving way to the more rounded one. Here we see again an interplay of gerontomorphism and paedomorphism, and that the Rhodesian and Saldanha skulls are expressions of this antithesis.

It is also worth noting in passing that the Saldanha skull is not alone amongst African primitives in having this laterally rounded shape of the vertex of the skull, because it is also shown by Eyassi man *(Africanthropus)*, with whom Saldanha man has other features in common. Thus the uniformly curved sagittal contour of the Saldanha skull parallels that of *Africanthropus*, but at a higher level. On the other hand the profile of the Rhodesian skull is very uneven with flattened facets on it.

There is a specially marked depression in the obelionic region of the latter (see fig. 1), which has usually been interpreted as signifying a marked degree of morphological primitiveness. More striking than this is the ultra-gorilline indentation which appears in this region of the endocast (see fig. 2). This latter has been regarded as indicating that the development of this important part of the brain has been specially retarded in Rhodesian man. Such an extreme degree of local arrest of development, however, is very unusual in human phylogeny, although there is some evidence of the same phenomenon in the mid-sagittal contour of endocast I of *Sinanthropus* (Weidenreich, '36).

Because it might have been expected that the Saldanha skull, being somewhat Rhodesioid, would show this depression and not the relatively more marked elevation present in this region, the question arises as to whether there may not be another explanation for this extreme inconsistency in the shape of these two skulls.

Figure 3 shows Morant's ('28) standard drawing of the transverse contour of the Rhodesian skull. Well up on the left side there is an indentation; this indentation and a depression in this region of the vault of the skull are very suggestive of post-mortem deformation. Opposite this, in an obliquely downward direction, the right basal part of the skull is missing and may have been broken inwards by counterpressure. It is interesting in this connection to recall that, according to one geological theory, the Broken Hill cave and the whole kopjie above it had suffered a general subsidence, and the skull, according to Harris ('21) had "tons of bones" above it.

Having mooted this possibility of deformation so that it may be kept in mind, should further evidence one way or another turn up, the writer will proceed on the assumption that the obelionic indentation is morphological, and it strengthens the present argument considerably to do so. The disharmony between the two endocasts in the region under discussion is acceptable in the light of the heteromorphism in other features of the two types being compared.

With regard to the braincasts in general there is no doubt, from measurements and calculations, that the relative smallness of the Saldanha cast, as shown in figure 2, substantiates a degree of cerebral inferiority in this type. This suggestion of primitiveness is endorsed by a consideration of the important occipital region of the skull and endocast. The squama of the occipital bone of the Saldanha skull is shorter and considerably narrower than that of the Rhodesian, and it has an area which is quite 15% smaller than that of the latter. This occipital plane also meets what there is of the nuchal plane of the Saldanha skull at a more primitive angle, than is shown by the Rhodesian (see fig. 1). In this respect the Saldanha skull agrees with the Neanderthals and lower types, whereas the Rhodesian disposition is quite sapient.

The impressions on the inner aspect of the Saldanha occipital bone, as reflected on the endocast, show that the occipital poles of the Saldanha cerebrum must have been rather feebly developed, whereas the corresponding pole of the Rhodesian is full and rounded (see fig. 2). In this respect the Rhodesian closely resembles the Neanderthals, whereas the Saldenha brain reverts more towards *Pithecanthropus* (see fig. 4). This inferior status is corroborated by the position of the cerebellum, which is little more than covered by the occipital pole of the cerebrum as in *Pithecanthropus,* whereas the Rhodesian cerebellum is in as forward and sheltered a position as in both sapient and Neanderthal brains (see fig. 4).

The degree of refinement of the occipital torus of the Saldanha skull, relative to this marked feature of the Rhodesian occiput, argues both ways. It may be an advance towards the condition found in many Australian skulls, which it resembles very much, but it must also be remembered that *Pithecanthro*- *us* has no torus occipitalis, and it is not very well developed n the typical Neanderthals.

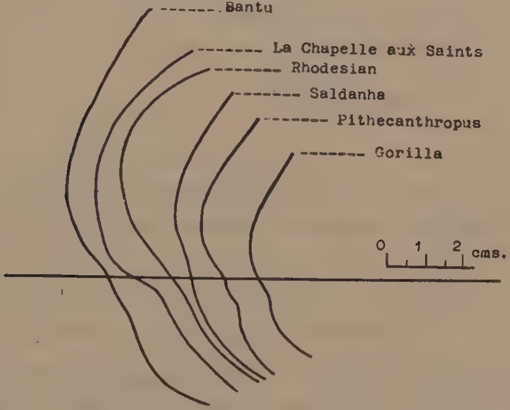

Fig. 4 Contours of the occipital region of a series of endocast (see text).

The last feature of Saldanha man which I wish to discuss is he mandibular fragment which we have presumed to belong o the Saldanha skull (Drennan and Singer, '55). There is no loubt that the features of this part of the ramus of a human nandible closely resemble those of the corresponding part of he Heidelberg jaw.

Heidelberg man was the first human fossil to show a square ibbon-like ramus and in this way to break away from the aller narrow ramus of the hominids and prehominids. By so doing he put himself on the early part of a genetic line which can be traced to the Neanderthals and to the later Khoisan types of South Africa.

To the extent that this shape of ramus is found in infantile mandibles it is a paedomorphic character, which, in those races that show it, defies the "stretch" put on the ramus by the erupting teeth. In other races the square shape of the infantile ramus is, so to speak, stretched into the relatively longer and narrower shape of the adult, so that as regards their mandibles they are gerontomorphs.

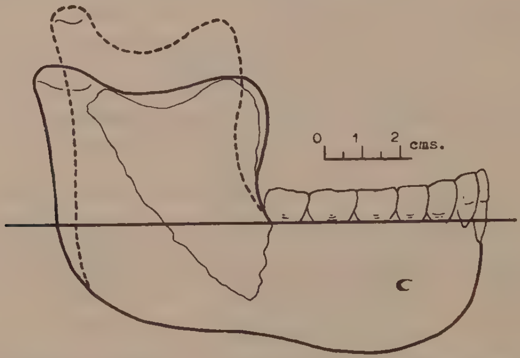

Fig. 5 Projection drawing of a cast of the Heidelberg mandible — continuous heavy line, with, superimposed on its ramus, the shape of this part of the mandible required by the Rhodesian skull — broken line. Thin continuous line represents the Saldanha fragment in its appropriate position.

It is a relatively easy matter to get an approximation to what the Rhodesian mandible must have looked like, and Dart ('55) has recently done this. In the skull itself we have the three factors that determine the length and breadth of the ramus, namely the mandibular fossa, which gives the upper limit of the condyloid process; the oval ring within the zygomatic arch, the long diameter of which determines the forward projection of the coronoid process; and the upper teeth which give the occlusal plane and the position of the lower teeth. It requires a relatively long and narrow ramus to conform to the three determinants I have mentioned, so that there can be no doubt that Rhodesian man was gerontomorphic in this respect.

Figure 5 gives a drawing of the ramus of the author's reconstruction of the Rhodesian mandible superimposed on the ramus of the Mauer jaw. On this latter also I have placed a drawing of the fragment of the Saldanha mandible in its appropriate position. The indications from this latter comparison are that the Saldanha mandible had a short wide ramus closely resembling that of Heidelberg man, and that both are relatively paedomorphic. If, therefore, the argument from this admittedly inferential evidence about the shape of the Rhodesian and Saldanha mandibles is valid, these two types here present their greatest and most significant contrast.

SUMMARY AND CONCLUSION

In the foregoing discussion of the salient features of Saldanha man it has been recognized that, in order to arrive at a correct assessment of his morphological status, it would be adventageous to use as a comparative standard his nearest and best known compeer, namely Rhodesian man.

Although there is a degree of resemblance between the skulls of these two fossil men, analysis of their features nevertheless shows that, far from having been cast in similar moulds, they show a wealth of contrast.

It is reasonable to deduce from this that, whatever their relative status may turn out to be, it will not be lineal but collateral. Expressing gerontomorphism in practically all features, Rhodesian man seems to have some backward linkage with the Neanderthals, with *Sinanthropus*, with *Paranthropus*, and even with the gorilla, whilst he has a close forward linkage with the australoid types of *Homo sapiens*. Saldanha man, on the other hand, would appear to have some backward linkage with a Heidelberg type of Neanderthal, with *Africanthropus*, with *Pithecanthropus*, and ultimately perhaps with some giant gibbon, whilst judging by his jaw and other paedomorphic tendencies he has some forward linkage with the South African paedomorphic types of *Homo sapiens*.

It is not an easy matter to assess the relative position of Rhodesian and Saldanha man on these two separate lines. Rugged and primitive as the features of the former obviously are, one is forced to regard these as relatively late specializations, because his undoubted predecessors were not so crude anatomically. The relative refinement or paedomorphism of the Saldanha skull, which might argue for a higher morphological status than that of the Rhodesian, need not therefore do so, all the more so as it shows no advance in cerebration. It is in fact the relative smallness and the primitive features of the Saldanha brain cast that do most to establish the Saldanha skull on a lower morphological grade. When with this there is taken into account the great thickness of the bones and other distinctive features of the Saldanha skull, the author considers it logical to designate Saldanha man as *Homo saldanensis.*

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THE AGE OF THE AUSTRALOPITHECINES OF SOUTHERN AFRICA

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NINE FIGURES

INTRODUCTION

Few problems in paleoanthropology have proved more dif-icult of solution than that of determining the age of the ustralopithecines of southern Africa. For a reasonable evalu-tion of the taxonomic and phylogenetic significance of these reatures it is imperative that the temporal relationships of he sites be known and their relative age established with eference to the late Cenozoic sequence south of the Sahara. impson ('52) has appropriately noted that inferences on the ffinities of this hominoid group must be "rather sterile" ithout this "most essential historical datum."

The problem of dating the australopithecines is threefold. irst, it is necessary to determine the chronological relation-hips of the australopithecine localities with reference to one nother. Second, the chronology thus established must be elated to what is known generally of the late Cenozoic suc-ession south of the Sahara. This has a direct bearing on the emporal relationships of the australopithecines and the arly stone industries. Finally, these results must be compared ith what is known elsewhere in the Old World. The last s particularly important since the chronological relationships f the australopithecines and the East Asian hominids from orth China and Java must be elucidated for purposes of orphological comparison and phylogenetic interpretation. hese three aspects of the problem will be examined in this aper.

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In the past, various estimates have been made of the relative geological age of the australopithecines and the temporal sequence of the various localities. Haughton ('47) suggested that the sites were not much separated in time. He regarded the sand and soil which constitute the breccia as having accumulated under semi-arid conditions, subsequently consolidated by percolating calcareous waters, and finally denuded by surface erosion of the landscape under more humid conditions. This interpretation was regarded by King ('51) as "inherently the more correct" and he equated all the australopithecine-bearing breccias which he termed 'older red sands.'

Cooke ('38, '41) was once inclined to assign different ages to the sites, ranging from late Lower to early Upper Pleistocene. He (in Haughton, '47) later agreed that the sites were more likely of the same general age and assigned all of the sites to the Lower Pleistocene, equated with an interval of aridity between an Older and Younger Pluvial stage; at this time the Villafranchian stage was attributed to the Upper Pliocene.

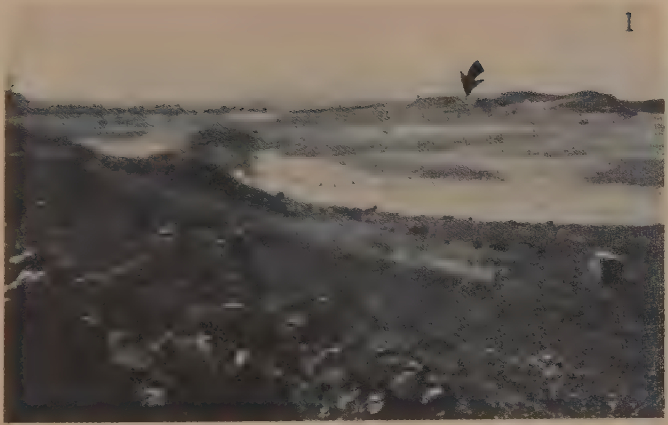
Other workers, particularly Broom ('50 and elsewhere) and Robinson ('52) have maintained that the australopithecines are older and of several distinct ages. Broom regarded Limeworks Cave, Taungs, and Sterkfontein (in that order) as the oldest deposits, which he attributed broadly to the Upper Pliocene; Kromdraai he thought to be the youngest and probably Lower Pleistocene. Robinson has agreed in principle with this interpretation, finding it "difficult to avoid the conclusion that the youngest of these deposits is not later than Lower Pleistocene" and Upper Pliocene "the most reasonable date as an approximation for the deposits as a whole."

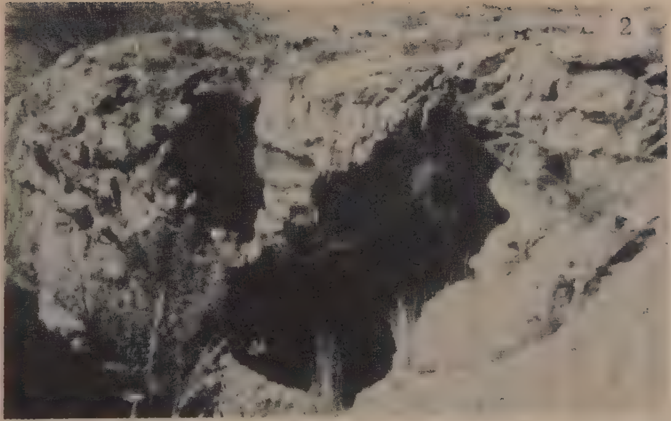
As more has become known of the stratigraphy of the australopithecine sites as well as the late Cenozoic sequence south of the Sahara, a more precise correlation with specific stages has become possible. Utilizing a variety of paleoclimatic and paleontological evidence, Oakley ('54a, '54b) has concluded that all the australopithecine-bearing breccias are of Pleistocene age. This interpretation, which has been supported by the author (Howell, '54), ranges the earliest sites (Limeworks Cave, Sterkfontein, and Taungs) in the final phases of the first (Kageran) pluvial stage and the succeeding drier end-pluvial, and the later sites (Swartkrans, and Kromdraai) in the early part of the second (Kamasian) pluvial stage. As a result of a careful re-examination of the evidence, the writer now believes that an alternative correlation can be made for the australopithecine deposits with the late Cenozoic succession south of the Sahara.

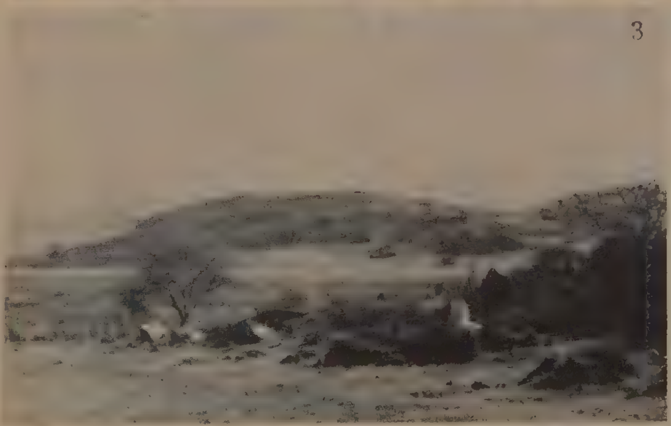
Description of the sites

Five different sites in three separate localities have yielded australopithecine skeletal remains. Three of these (Sterkfontein, Swartkrans, and Kromdraai) are located in a shallow valley about 6 miles northwest of Krugersdorp in the southern Transvaal. The country is rolling, high veld (4850 feet) with relatively low relief and few trees or bushes except along some small watercourses. This is limestone country, the australopithecine-bearing deposits occurring in solution cavities and fissures of the Dolomite Series of the Transvaal System (figs. 1–4). At present it is relatively dry with an average summer rainfall of about 28–30 inches.

The Makapansgat valley, in which the Limeworks Cave is situated, is a few miles northeast of Potgietersrust in the central Transvaal. This is bushveld country with a slightly lower (25-inch) annual rainfall. At its eastern (or head) end a small stream pours over a waterfall and flows about a mile before vanishing underground. At the same end of the valley there is a relict of Knysna forest with assegai, yellowwood, Cape holly, wild pepper and tongue fern indicative of a past climate quite different from that of the present (figs. –7). A number of other, younger caves are present at higher levels in the limestone hillsides of the valley; these have yielded rich evidence of human occupation during the late Middle and Upper Pleistocene.







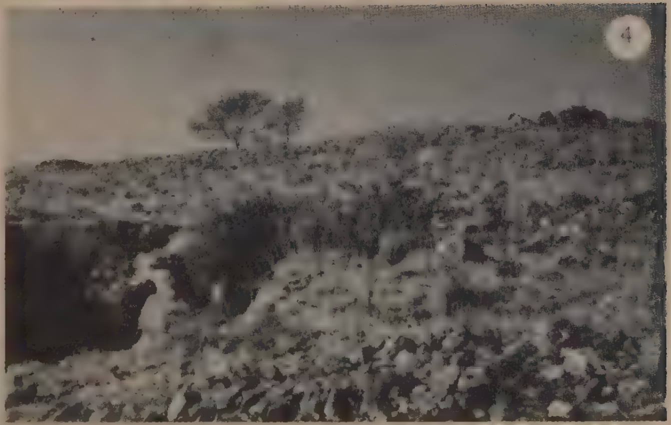
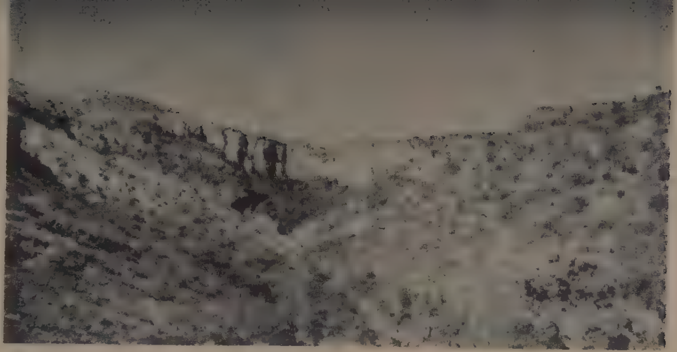
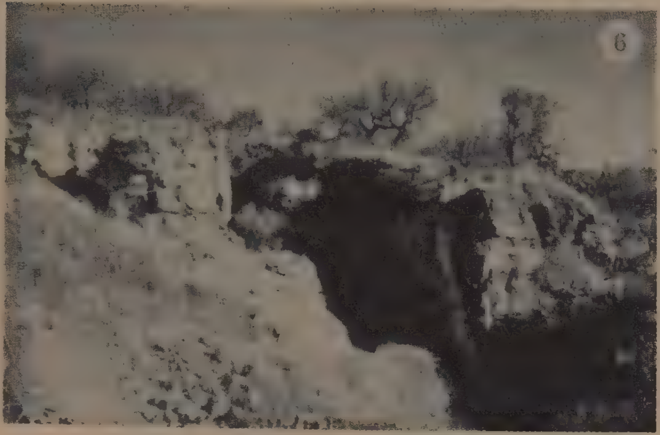


Fig. 1 View across the Sterkfontein valley looking east from Swartkrans. The Sterkfontein caves are in the hill indicated by an arrow; the





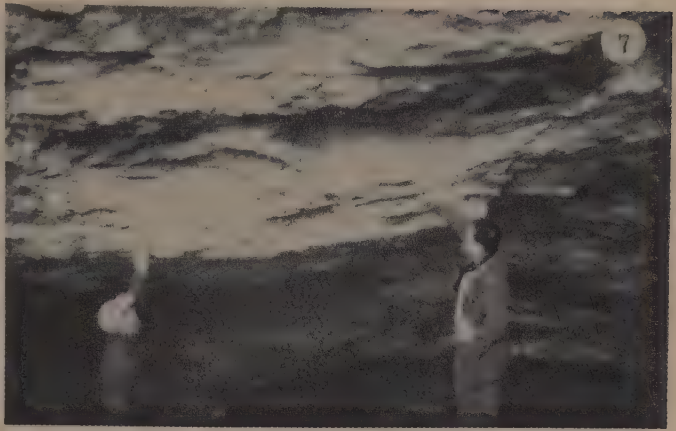


Fig. 5 View towards the eastern (head) end of Makapansgat Valley. The dark mass of vegetation (arrow) below the eroded mid-Tertiary land surface is a relict of Knysna forest.

Fig. 6 View towards the eastern entrance of Limeworks Cave, Makapansgat Valley.

Fig. 7 Breccia deposits suspended from the roof after mining of the basal travertine at Limeworks Cave. Mr. Revil Mason (left) is pointing to the basal gray (australopithecine-bearing) breccia and Professor C. van Riet Lowe (right) to the overlying pinkish breccia.

The first site from which australopithecine remains were recovered (in 1924) was a lime workings at Buxton, near Taungs, Bechuanaland just west of the Transvaal border. Unlike the other sites this cave was developed in a cliff-forming travertine banked up against a Transvaal Dolomite of the Campbell Rand Series. Mining activities have now destroyed all traces of the original cave. The climate is drier here than farther to the east, having an annual average rainfall of about 17 inches.

All of the australopithecine fossils have come from sites which were worked commercially for lime; quarrying activities have usually removed the rich underlying travertine deposits leaving the higher bone-bearing breccias suspended from the roof and undermined or broken up and thrown on dump heaps. The details of the original cave stratigraphy were not always recorded immediately and were sometimes obscured or even destroyed (as at Taungs). This fact is responsible in part for the discrepancies in relative dating of the sites by different workers.

In recent years careful study of the remaining deposits in the Krugersdorp area (Robinson, '52; Brain and Robinson, '53; C. K. Brain, personal communication) and in Makapansgat valley (Dart, '47; Brain, van Riet Lowe and Dart, '55) have made clear the mode of accumulation of the deposits and the sequence of events at these sites. Peabody's ('54) recent study of the travertine and cave accumulations along the Kaap escarpment permits a reconstruction of the events leading to the deposition in the ''Australopithecus'' (or Dart's) Cave with a considerable degree of assurance. These investigations and careful sampling and petrographic analyses of the various fossiliferous breccias and the modern dolomite soils by C. K. Brain (Transvaal Museum) permit a unique evaluation of the climatic conditions which prevailed at the time the australopithecines lived in southern Africa.

Several methods of analysis have been employed to throw light on past climatic conditions. These include: (1) percentages of carbonate content (greater amounts indicate greater aridity) (cf. Cooke, '38; and King, '51); (2) percentages of weathered dolomite fragments (greater amounts indicate greater aridity) (cf. Cooke, '38; Haughton, '47; and King, '51); (3) variations in coloration of breccias (pink indicative of aridity, brown indicative of humidity); (4) percentages of wind-rounded sand grains (indicative of aeolian activity) (Brain, 1955: Third Pan-African Congress on Prehistory, Livingstone, Northern Rhodesia); (5) percentage ratios of chert (local dolomitic derivation) and quartz (of extraneous origin) grains (a measure of aeolian activity) (Brain, ibid.); (6) evidences of breccia stratification (a measure of water action in deposition) (Robinson, '52).

The successions and their broad climatic significance are briefly summarized below.

Sterkfontein cave

Basal sandy travertine → Reddish-pink breccia with dolomite blocks (australopithecine level) → Stalagmite and dripstone infilling fissures.
Interpretation: drier → wetter.

The cave system at Sterkfontein is extensive and mammalian fossils have been recovered from several different localities. Australopithecine remains have been found only at one locality (designated Sterkfontein Type Site) which is an open quarry in a fissure at the top of the hill.

Dart's cave (Taungs)

Thabaseek travertine with underlying apron and overlying carapace → Cave formed in carapace → Reddish, calcified sandy breccia → Contaminated travertine with intercalated lenses of red sand (probable australopithecine level).
Interpretation: (wetter) → drier → wetter.

Limeworks cave

Basal travertine → Gray (australopithecine level) or light pink breccia, heavily calcified and with dolomite blocks → Sandy level containing water-rounded pebbles → Red-brown breccia with inclusions of pebbles in a sandy matrix in places.
Interpretation: drier → wetter.

Swartkrans cave

Basal travertine → Gray breccia and dripstone (banded travertine) → Orange (below) to pink (above) breccia with dolomite blocks (australopithecine level) → Disconformity due to floor collapse → Brown stratified breccia.
Interpretation: moderately wet → wet.

Kromdraai hill fissure

Isolated outcrop of brownish breccia, partly stratified (australopithecine level).
Interpretation: wet.

The type adult australopithecine remains from the Kromdraai hill site were found in 1938 by a schoolboy from a limited exposure o breccia. In 1941 a child's mandible was recovered from the same exposure ''within four feet of the place where the type skull lay'' (Broom and Schepers, '46). This exposure, termed the ''Child Mandible Site'' (Site A) provided little determinable associated fauna. About 70–80 yards away, however, a large outcrop of brownish breccia, termed the ''Kromdraai Faunal Site'' (Site B), has provided a rich fauna which is here regarded as of approximately the same general age or perhaps slightly older. Recently, 1955, australopithecine remains have been found in this breccia also which is now known to be an extensive one.

In general the evidence favors a drier climate at the time of formation of australopithecine-bearing breccias at Sterkfontein than during formation of those at Swartkrans and Kromdraai. At Sterkfontein the climate was drier than, at Swartkrans about the same as and at Kromdraai wetter than present climatic conditions in the same vicinity. At Limeworks Cave a sequence humid-arid-humid-arid-humid was described by Dart ('47) on the basis of work by Bosazza, Adie and Brenner ('46), and King ('51) later described the same sequence Brain's recent re-examination (in Brain, van Riet Lowe and Dart '55) of the stratigraphy at this site has shown that the basal deposit (gray and pink breccias) were slowly accumulated when the opening of the cave was small and not yet in equilibrium with the outside subsequently, with the establishment of a larger opening, there wa rapid introduction of material. This event apparently denotes a change from drier to wetter conditions.

Peabody ('54) has recently shown that an earlier, drier, and a later, wetter series of deposits must have been present in the cav developed in the Thabaseek travertine at Buxton. There is some evidence to suggest that the type skull of *Australopithecus* probably cam from the later horizon. The travertines were very likely formed under a climatic regime which was not fully ''pluvial,'' but rather like that at the initiation or decline of either a humid or arid period.

The faunal evidence

The mammalian faunas from the australopithecine sites afford the best evidence for determining their temporal relationships. The presence or absence of certain archaic or modern genera and species in an assemblage can be employed as an indicator of relative age differences. There are definite drawbacks to this method since the fauna recovered from any one site obviously is not necessarily a complete representation of the local fauna at the time the deposits were accumulated. The manner in which the fauna, including the australopithecines, came to be incorporated in the caves is an important factor about which there is little common agreement. In the future it is surely important to know whether these caverns were: (1) australopithecine living sites and the fauna ''kitchen debris''; (2) rubbish heaps into which were thrown (presumably by the australopithecines) australopithecines and other animal remains; (3) carnivore lairs and the fauna prey or scavenged material; (4) natural cavities and fissures into which accumulations of bone were swept by natural agencies. The first and last explanations have little field evidence to support them and the second and third appear inherently more probable in the writer's opinion.

Cooke ('51) was among the first to point out that the evidence ''favours a broad correlation of the ape-man fauna with the lower Quaternary stage known as the Villafranchian.'' This stage, as is now well known, is defined on the basis of the first appearance of the modern genera of equids *(Equus)*, bovids *(Leptobos)* and proboscideans *(Elephas* of the *meridionalis-planifrons* group). A number of archaic, late Tertiary (and earlier) genera are also found in Villafranchian assemblages, but it is the appearance of certain distinctive new forms which is characteristic of the stage. In both Europe and Asia there is incontrovertible evidence of orogenic movements prior to this stage, but subsequent to the late Pliocene deposits, and of a generally cooler climate as the stage was initiated. On climatic and other grounds the stage must be regarded as basal Pleistocene.

TABLE 1

Major elements of the associated mammalian faunas from the australopithecine-bearing breccias of southern Africa

	STERKFONTEIN	TAUNGS	LIMEWORKS CAVE	SWARTKRANS	KROMDRAAI
Stylohipparion			--------	-------	
Equus (zebra)			--------	-------	------
Equus (horse)					------
Metaschizotherium			--------		
Griquatherium			--------		
Giraffa			--------		
Hippopotamus			--------		
Pronotochoerus			--------		
Notochoerus	-------				
Potamochoeroides			--------		
Lycyaena	-------			-------	
Leecyaena				-------	
Crocuta			--------	-------	------
Hyaena	-------		--------	-------	------
Paracynictis				-------	
Canis	-------			-------	------
Megantereon	-------			-------	------
Epimachairodus					---?--
Felis					------
Panthera	-------			-------	------
Therailurus	-------			-------	------
Parapapio	-------	-------	--------	-------	------
Dinopithecus				-------	
Simopithecus			--------	-------	
Papio				-------	------

There is a rough correlation among the australopithecine faunal assemblages between archaic faunas and drier climates and more modern faunas and wetter climates. In general the associated faunas from Sterkfontein and Taungs are more primitive than those from Limeworks Cave, Swartkrans and Kromdraai (table 1). At both former sites modern equids are missing, modern baboons are missing and at Sterkfontein, where a carnivore fauna is known, modern carnivores are absent. On faunal grounds the sequence, Sterkfontein — Limeworks Cave — Swartkrans — Kromdraai, is fully justifiable. The associated fauna from Dart's Cave at Taungs is almost exclusively represented by small forms (rodents, hyraxes, shrews) of which a good percentage of the genera (5 of 15) and all of the species are probably extinct (Broom and Schepers, '46). An age roughly equivalent to Sterkfontein, perhaps either slightly older or younger, is reasonable, but there is little specific faunal evidence to prove the point either way.

A comparison of these assemblages with the late Cenozoic faunal succession south of the Sahara is complicated by several factors. The Vaal River basin has provided a Pleistocene chronology for the subcontinent, with 4 major pluvial stages separated by drier end-pluvials, but faunal remains are uncommon and none are certainly earlier than the late Middle Pleistocene. The fauna from deposits of this age, the Younger Gravels series, differs markedly from the assemblages found at the australopithecine sites, from the few forms common to both, and is more evolved and modern (Cooke, '49). For this reason correlations must be effected with the sequence established in eastern Africa. There the Pleistocene is well known, with 4 major pluvials separated by three drier end-pluvials, but evidence of the Pliocene is absent. Also, faunal comparisons are made difficult since the assemblages from eastern Africa are derived exclusively from riverine or lacustrine deposits in which for the most part only macrofaunal elements are preserved. A few useful forms are common to both the eastern Africa localities and the australopithecine sites including equids, rare giraffids, some felids and hyaenids, rare suids, and baboons.

In eastern Africa three important localities have provided faunas representative of the Lower Pleistocene. These are: (1) Omo River, north of Lake Rudolph (Arambourg, '43, '47); (2) Kanam, near Homa mountain on the southern shores of Kavirondo Gulf, an eastern embayment of Lake Victoria

(Kent, '42); (3) the Kaiso beds of the Western Rift Valley, between Lake Albert and the Rutshuru River south of Lake Edward (Wayland and others, '26; Lepersonne, '49). The lacustrine clays and sands at Kanam and Omo River are the oldest, of late first (Kageran) pluvial age, while the ironstone deposits of the middle Kaiso series are of later, end-pluvial (Kageran/Kamasian) age (cf. Leakey, '50). The faunas from these localities are typically Villafranchian and include various archaic forms (stegodont and mastodont proboscideans, tridactyl equids, a chalicothere, a machairodont sabretooth tiger, small hippopotami, a short-legged giraffe) as well as some more modern elements (primitive archidiskodont elephants of both the earlier *planifrons* and later *meridionalis* groups, true horse and zebra, and some evolved suids) (see table 2). This faunal stage, the *Kaiso* stage of Hopwood (in Leakey, '51), differs markedly from that of the early Middle Pleistocene found in deposits of the second (Kamasian) pluvial. The latter, as represented by the assemblage from Bed I at Olduvai Gorge (northern Tanganyika), lacks stegodonts, small hippopotami, machairodonts, or the earlier archidiskodont proboscideans. Some new forms are present in this later stage including an evolved archidiskodont elephant, a number of suids, and a giant sheep and bovine (cf. table 2). The faunal change between the Lower and early Middle Pleistocene is more marked than any subsequent change, both in the appearance of new forms and the extinction of old forms (MacInnes in Leakey, '51).

The occurrence of modern equids at Swartkrans and Kromdraai, and in the pink breccia at Limeworks Cave, indicates that these sites can be no older than Lower Pleistocene, i.e., the Villafranchian stage. (No horse remains have been found in hill-top quarry at Sterkfontein where australopithecine fossils are present, although horse is known from other localities, e.g., Graveyard Site, in the hill). Recently, Oakley ('54a, '54b) has equated the first two sites with the early Middle Pleistocene, but there is some evidence to link all three with the Villafranchian stage. A giant baboon, *Dino-*

pithecus, has been found at Swartkrans; this form is found in eastern Africa *only* in assemblages of the Villafranchian stage (at Omo River). Another baboon genus, *Simopithecus*, is characteristic of the Middle Pleistocene in eastern Africa (allied varieties are known in northern Africa), but it is already present in the Villafranchian stage (at Kaiso); this form is present at Limeworks Cave and Swartkrans. The short-faced baboon *Parapapio* is characteristic of all the

TABLE 2

or elements of the Villafranchian and early post-Villafranchian mammalian faunas in eastern Africa. (The taxonomy for the fossil suids is based on revisions and synonomies to be published soon in a study by L. S. B. Leakey)

LATE KAGERAN PLUVIAL Omo River — Kanam	END-PLUVIAL Middle Kaiso Beds	EARLY KAMASIAN PLUVIAL Olduvai Gorge: Bed 1
on – – – – – – – – – – – – – – –	– – – – – – – – – – – – – – +	
ophodon – – – – – – – – – – – – +		
herium – – – – – – – – – – – – –	. . . .	– – – – – – – – – – – – – – –
us – – – – – – – – – – – – – – –	. . . .	– – – – – – – – – – – – – – +
s (Archidiskodon) – – – – – – –	– – (*griqua*) – – – – – –	– – – (*recki*) – – – – – –
ipparion – – – – – – – – – – – – –	– – – – – – – – – – – – – – –	– – – – – – – – – – – – – – –
– – – – – – – – – – – – – – – – –	– – – – – – – – – – – – – – –	– – – – – – – – – – – – – – –
hizotherium	– – – – – – – – – – – – – – –	– – – – – – – – – – – – – – –
erium – – – – – – – – – – – – – –	– – – – – – – – – – – – – – –	– – – – – – – – – – – – – – –
– – – – – – – – – – – – – – – – –	– – – – – – – – – – – – – – –	. . . .
hus . . . . ?	. . . . ?	– – – – – – – – – – – – – – –
vis . . . . ?	. . . . ?	– – – – – – – – – – – – – – –
potamus (protamp., immagun.)	– (*immagun., kaisen.*) –	– – (*gorgops*) – – – –
ochoerus – – – – – – – – – – – – –	– – – – – – – – – – – – – – +	
oerus . . . . ?	– – – (*euilus*) – – – – – –	– – (*compactus*) – –
oerus – – – (*heseloni*) – – – –	– – (*limnetes*) – – – – –	– – (*olduvaiensis*) – –
oerus		– – – – – – – – – – – – – – –
tonyx		– – – – – – – – – – – – – – –
ochoerus		– – – – – – – – – – – – – – –
ochoerus		– – – – – – – – – – – – – – –
hoerus		– – – – – – – – – – – – – – –
a	. . . . . ?	– – – – – – – – – – – – – – –
a – – – – (aff. *brunnae*) – – – –	. . . .	. . . .
herium – – – – – – – – – – – – –	– – (*Machairodus*) – – +	
thecus – – – – – – – – – – – – – +		
thecus	– – – – – – – – – – – – – – –	– – – – – – – – – – – – – – –

australopithecine-bearing breccias and is unknown in other parts of Africa. True *Papio*, the living baboon genus, is found only at Swartkrans and Kromdraai. Forms like the chalicothere and the short-legged giraffe present at Limeworks Cave (George, '50; Cooke and Wells, '47), and the tridactyl horse from there and Swartkrans, are archaic elements which in eastern Africa survive into the Middle Pleistocene.

Three australopithecine sites, Sterkfontein, Swartkrans and Kromdraai, have yielded remains of machairodont sabretooth tigers (Broom, '39, '48; pers. comm. from J. T. Robinson, C. K. Brain, and R. F. Ewer). These forms are found in deposits of the Villafranchian stage (Omo, Kaiso) in eastern Africa, but are unknown in Middle Pleistocene deposits south of the Sahara. Machairodonts are known to persist into the Middle Pleistocene of northern Africa only at the site of Palikao (Algeria) (Arambourg, '52). At Sterkfontein modern hyaenids are very rare (only two fragments of *Hyaena* sp.) (Ewer, '54b, '54c), and the primitive form *Lycyaena* is most characteristic. This creature is also found at Swartkrans (Ewer, '54c) but there it is associated with the modern genera of spotted *(Crocuta)* and striped *(Hyaena)* hyaena. At Limeworks Cave (Toerien, '52) and at Kromdraai (Ewer, '54a) only the modern genera are represented. In general the carnivore fauna from Sterkfontein is more primitive than that found at any other australopithecine site; in some respects, particularly in the presence of *Lycyaena*, even more primitive than Villafranchian assemblages from eastern Africa.

In Asia, *Lycyaena* is known from the Lower (Chinji Zone) and Middle (Dhok Pathan Zone) Siwaliks, deposits of Lower and Upper Pliocene age, respectively; it is unknown in any later horizons. The genus *Crocuta* is already present in the Upper Miocene (Tung Gung formation, Mongolia) and is well known throughout the Siwalik series. The group within the genus to which the African forms belong is first found in the later Pliocene. The species (cf. *brevirostris*) found at

A tentative correlation of the australopithecine-bearing breccias with the Pliocene-Pleistocene sequence south of the Sahara

		EASTERN AND CENTRAL AFRICA			STONE INDUSTRIES	SOUTHERN AFRICA	
		EASTERN RIFT VALLEY	KAGERA RIVER	WESTERN RIFT VALLEY		VAAL RIVER	TRANSVAAL CAVES
KAMASIAN	1	Olduvai Gorge Bed 1. Buff-colored volcanic tuffs, wind-transported and water-deposited. + 100′	Basal Boulder bed of the 100′ terrace at Nsongezi.	Kaiso 3. Alternating sands, clayey-sands and fine gravels. 40–50 m.	OLDOWAN | |	Older Gravels. (non-diabasic)	
END-PLUVIAL		Volcanic activity and earth movements.	Riverine sands.	Kaiso 2. Alternating clays, sands, and thin pebble beds; many lenticular limonitic levels (= bone beds). + 125–200 m.	↓ ? ↑	Kalahari Sand redistribution. Calcification. Gravel redistribution.	
KAGERAN	3	Omo River. Alternating sandstones, fine sands and gravels, and clayey volcanic tuffs (bone-beds), all tilted.	200′ Terrace Gravels.	Kaiso 1. Alternating stratified sands, clays and gravels. 40–50 m.	| DEVELOPED KAFUAN | ↓	↑ Basal Older Gravels. (diabasic) ↓	Kromdraai (CMS) breccia Swartkrans pink breccia Limeworks Cave gray breccia ↑
	2	Gaza lacustrine beds (?)	270′ Terrace Gravels. Bumona sandstones.	Disconformity.	↑ LATER |		Taungs (upper) breccia |
	1		Bumona-Ibanda laterites and conglomerates.	Unstratified, indurated coarse clayey-sand. Basal lateritic conglomerate.	EARLIER | KAFUAN ↓	Erosion of Vaal River.	Sterkfontein pink breccia | ? ↓
				PLIOCENE	– – – PLEISTOCENE BOUNDARY		
LATE PLIOCENE		Unknown.	Unknown.	Unknown.		Kalahari Sands.	

Limeworks Cave apparently resembles most closely a Villafranchian form of Europe (from the St. Prestian stage). At Swartkrans a distinctive species of spotted hyaena is present and another which is only subspecifically distinct (Ewer, '54b). One spotted hyaena *(C. spelaea capensis)* from Kromdraai resembles, but is more primitive than, the European cave hyaena; another distinct species is also present. The *Hyaena* remains from Limeworks Cave and Swartkrans resemble the living species *(hyaena, brunnea)*, while a striped hyaena *(H. bellax)* from Kromdraai has an important resemblance to a European Villafranchian form. R. F. Ewer ('54b and Third Pan-African Congress on Prehistory, Livingstone, Northern Rhodesia, 1955) has pointed out that 41% of the genera and 81% of the carnivore species at the Krugersdorp sites are extinct forms and that the total faunas suggest an age no later than the Kageran pluvial stage. The carnivores by themselves are not particularly useful in age determinations; but they do offer confirmatory evidence when the whole fauna is taken into consideration and do not controvert, but in some respects support, a Villafranchian age for the australopithecine deposits as a whole.

Suid remains are poorly represented in the australopithecine-bearing breccias (those reported are now under study by R. F. Ewer). An extinct species of hippopotamus is known only from Limeworks Cave (Kitching, '51) where there was likely to have been permanent water in the valley. A primitive wart-hog, *Pronotochoerus*, has been recorded from the Limeworks Cave (Dale, '48); this is possibly a primitive species of *Mesochoerus* (Leakey, pers. comm.) which is found in both Lower and Middle Pleistocene deposits in eastern Africa. A peculiar form, *Potamochoeroides*, resembling a bush-pig, is also present at that site. At Sterkfontein a giant wart-hog *(Notochoerus)* is represented (Broom, '48), although this may possibly be the smaller form *Tapinochoerus*. A questionable *Mesochoerus* may also be represented. Suid remains are unknown at Taungs. They are present at Kromdraai and at Swartkrans, but are still to be studied and described.

In general the faunal evidence suggests that the youngest australopithecine sites are older than Middle Pleistocene and are in fact most likely Villafranchian. There is no diagnostic element at either Sterkfontein or Taungs which would aid in placing either site in the Pliocene or Pleistocene. At Taungs, however, there is some indirect evidence which suggests a Pleistocene age. Peabody ('54) has described a travertine formed below the Kaap escarpment at Boetsap, south of Buxton, which appears to be older than the Thabaseek travertine in which the original "*Australopithecus*" cave was developed; the former has yielded remains of horse, wart-hog and antelope (no specific determinations). The presence of *Equus* at this locality would indicate that Taungs at least is probably Villafranchian. There is inadequate evidence to prove it, but Sterkfontein is probably of the same general age.

DISCUSSION

At the three younger australopithecine sites there is evidence of an increased rainfall indicative of pluvial conditions. Since the faunal evidence suggests a Villafranchian age for these sites, then Limeworks Cave, Swartkrans and Kromdraai should all fall within a later phase of the Kageran pluvial stage, but prior to the Kageran/Kamasian end-pluvial.

Recent investigations by Brain (in Brain, van Riet Lowe and Dart, '55) at Limeworks Cave provide some evidence in support of this interpretation. In a heavily calcified sandy soil overlying the basal pink and gray breccias, he found numerous waterworn and abraded pebbles, including quartzites from farther up the valley, representing a fluviatile deposit. Further work in this horizon in 1955 has yielded some faunal remains and a fragment of an australopithecine upper jaw with two molars (Dart, '55). This upper gravel-like accumulation is most probably evidence of a late Kageran wet phase and the underlying pink and gray breccias were likely accumulated slowly during a drier interstadial of this pluvial stage.

There is other evidence which indicates that the Makapansgat valley was flooded to a considerable height during parts of the Pleistocene, long after it had been cut into the mid-Tertiary erosion surface. Some 160–175 feet above the rubble and alluvial-filled floor of the valley there is a well marked bench on the 4750–4800-foot contour. This formation bevels off and exposes the breccia deposits in the Limeworks Cave. This bench, which has been mentioned already by Dart ('47) and Barbour ('49), was probably cut in the early Middle Pleistocene during the increased rainfall of the Kamasian pluvial stage, after the cavern was filled and the valley flooded late in the Kageran pluvial stage. (Barbour, however, thinks the bench "can hardly be much younger than Lower Pleistocene.") The original cave entrance must have been considerably higher than the top of the deposits at present so that the amount of erosion which has taken place since the deposits were accumulated is rather remarkable.

The sequence of travertine and cave deposits around Buxton, near Taungs, throws some light on the age of the earlier australopithecine site, Dart's Cave. This cave was formed in the oldest (Thabaseek) of 4 cliff-forming travertines on the western margin of the Harts River valley. The Kaap escarpment against which it is banked is a remnant of the pre-Karroo landscape and the travertine was accumulated in the oldest channel of the Thabaseek River, a small spring-fed stream which drains this plateau (Young, '25; Peabody, '54). It is difficult to imagine the Buxton travertines as having accumulated under conditions other than those which prevailed *after* the semi-arid and desertic Pliocene.

A lower limit for the age of the travertine can be established by determining the time of exposure of the cliff against which it was formed. Originally, the Vaal-Harts River flowed over Karroo rocks on a peneplain of about 4000 feet, comparable to the present Kaap plateau and corresponding to the mid-Tertiary land surface (du Toit, '10). Subsequently, the Ecca shales and Dwyka tillites of the Karroo System were cut through and the river deepened its bed by cutting into the resistant underlying pre-Karroo rocks (Ventersdorp diabase, Transvaal dolomites, etc.). Cooke ('46, '47) suggested that this occurred when the Older Gravels of the Vaal River were aggraded. It is very probable, however, that some downcutting had taken place even earlier when the Basal Older Gravels were aggraded since these underlie the Older Gravels at a number of sites (Breuil, van Riet Lowe and du Toit, '48) and rest directly on Ventersdorp lavas. The Basal Older Gravels consist of diabasic elements for the most part (90–95%), much of which has been derived from the Dwyka Conglomerates, but some also surely from the pre-Karroo exposures. The gravels evidently lie where they were first deposited, but judging from "their occurrence at varying altitudes (3680–3725 feet) above the present river bed" they pretty clearly "represent a series of deposits belonging to different resting stages in the progressive downward cutting of the ancient river" (Cooke, '46). It seems very likely that this cliff was exposed toward the end of the Pliocene as the rainfall increased with the onset of the first African pluvial stage. An early Kageran age for the Thabaseek travertine and an interstadial age for the deposits in Dart's Cave accords well with the available evidence.

Unfortunately, it is still impossible to subdivide on climatic grounds the lower Pleistocene in southern Africa. The Kageran pluvial is represented only by isolated occurrences of river gravels, and sections indicating the continuity from late Pliocene through the basal Pleistocene are still unknown. The evidence for the Kageran pluvial stage is much better in eastern Africa where lacustrine deposits in closed basins reveal continuous sedimentation. There too, however, the Pliocene is still obscure. In both eastern and southern Africa the duration and complexity of the Kageran pluvial stage are unsettled due to lack of good exposures. In central Africa an at least two-fold subdivision of the first pluvial stage is suggested by the 270- and 200-foot terraces of the

Kagera River in Uganda. Wayland (pers. comm.; *in litt.*), however, has pointed out the presence of older laterites, lateritized conglomerates and sandstones (Ibanda, Bumona series) which indicate earlier humid climatic conditions which are post-Tertiary. In the southern and eastern Congo there are pediplaned surfaces cut into deposits overlying the end-Tertiary erosion surface which are earlier than typical Kageran pluvial deposits (Cahen and Lepersonne, '52; Cahen, '55). These levels are complex and still poorly known, but surely indicate a shift from arid or semi-arid conditions of the late Pliocene toward the wetter climate denoting the Kageran pluvial stage and thus, the Pleistocene period. On climatic grounds some of the "pre-Kageran" surfaces must in fact represent the basal Pleistocene and probably testify to early stadials within the Kageran stage. In the future detailed confirmation will probably be forthcoming from the lake basins of central and eastern Africa where the sedimentary record is best preserved; it is very likely that these earlier deposits are preserved in the center rather than on the periphery of the basins and coring will be necessary to reveal them.

It is to be expected that such evidence will be forthcoming south of the Sahara since it is already available in Europe in the form of the earliest (Danubian) glacial stages in the Alps. Such stages are apparent from high-level fluvioglacial terraces in the Wertach and Lech valleys of the Schwabian foothills (Eberl, '30; Schäfer, '53), and from "pre-Günz" lacustrine deposits in the Leffe basin in Lombardy which have provided a continental Villafranchian faunal assemblage (Venzo, '52, '53). There is now considerable evidence in favor of two or three cool Danubian phases prior to the main first (Günz) glaciation (itself probably two- or three-fold) or its marine equivalent, the Calabrian.

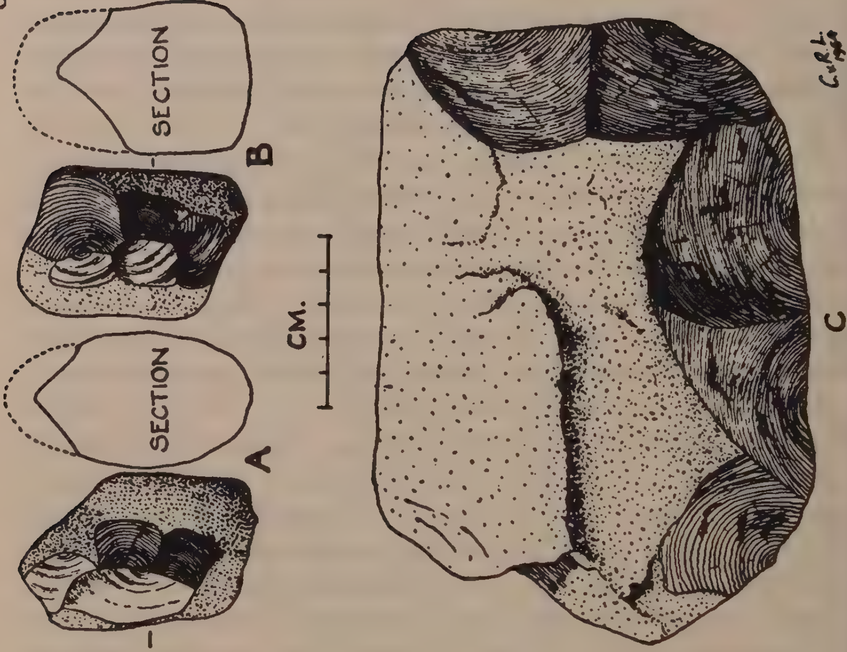
The temporal priority of the earliest australopithecines, on the basis of Oakley's dating, has already been noted (Howell, '54). Sufficient evidence is now available to attribute the whole of the australopithecine group to the lower Pleistocene. At this time, hominids and tool-making are unknown outside the African continent. Outside Africa, the first hominids (true members of the genus *Homo*) and the first handaxe and chopper/chopping-tool industries are found in deposits of the early Middle Pleistocene.

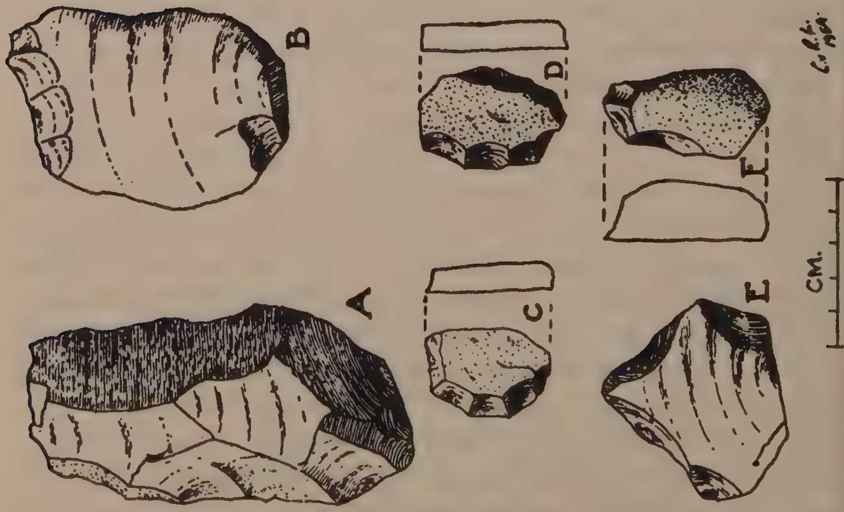
The evolutionary implications of the Villafranchian age of the australopithecines is only now becoming evident. These forms, which fall taxonomically into two main groups (of subgeneric status in the author's opinion), had already attained a stage of primitive bipedalism (Howell, *in litt.*). They were small-brained, big-faced primitive hominids whose orthograde progression permitted an active ground-dwelling existence in open savannah country.

The younger members of the group exhibit a pattern of skeletal morphology which suggests that they represent a specialized derivative of an earlier, probably Pliocene, radiation of an original still-unknown australopithecine stock. There is still no trace of such forms in Europe. A younger and related species (*Meganthropus* from the Djetis Beds in Java) from Southeast Asia indicates that australopithecine-derivatives had reached this area by the early Middle Pleistocene. The present evidence suggests strongly that the initial radiation occurred in Africa and, after further adaptation to a ground-dwelling existence, such forms spread into other areas of the Old World.

The relationship, if any, between these creatures and the earliest Pre-Chelles-Acheul or pebble-tool industries in southern Africa is still an open question. Australopithecine remains and pebble-tools have never been found at the same site; australopithecines occur only in fissure and cave fillings and Pre-Chelles-Acheul pebble-tools are found only in riverine and lacustrine deposits. A small series of supposed pebble-tools (fig. 8) have been reported from the fluviatile deposit at Limeworks Cave, but there is some evidence which suggests that these may very well be naturally flaked dolomitic limestone. On the other hand, unless these limestone caves were actual habitation sites (and this has never been proved)

8





it is not to be expected necessarily that actual pebble-tools would be found in them. Pebble-tools of this age, referred to an advanced stage of the Kafuan industry, do occur *in situ* in the upper part of the 200-foot terrace gravels of the Kagera River in southern Uganda (van Riet Lowe, '52) and

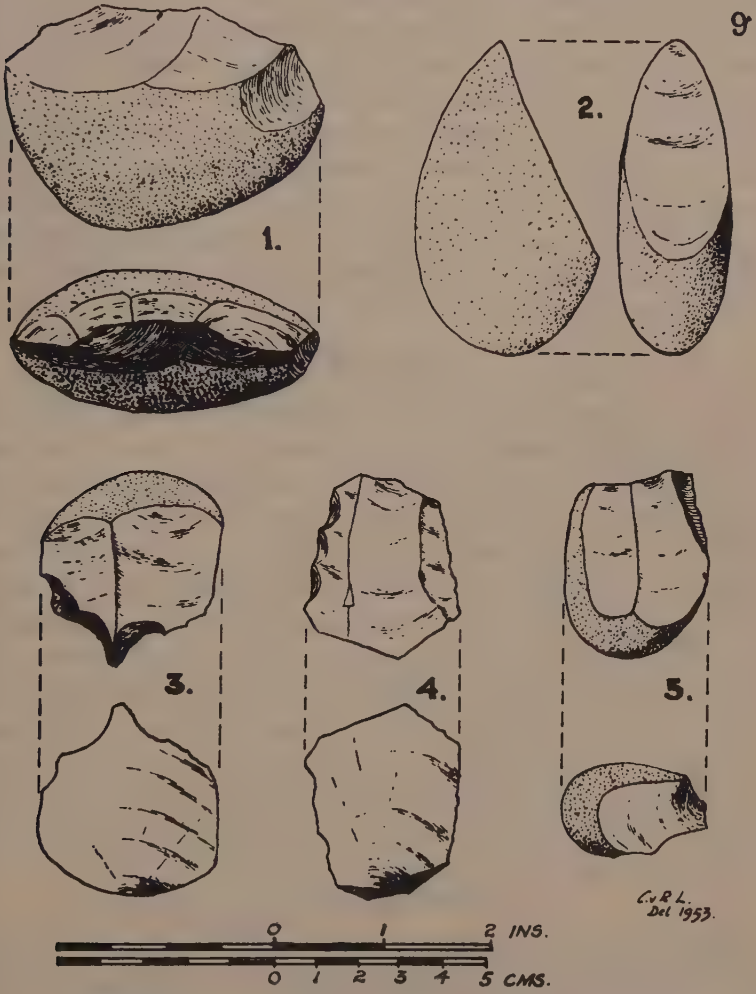


Fig. 9 Chopping-tool, split-pebble, flakes and a core representative of an evolved stage of the Kafuan pebble-tool culture from the (redistributed) Basal Older Gravels of the Vaal River. (One-half natural size.) (After van Riet Lowe, '55.)

in situ in the upper, disturbed portions of the Basal Older Gravels of the Vaal River (van Riet Lowe, '53) (fig. 9). It seems likely that such implements were usually produced and utilized on the spot and then discarded when no longer needed for a particular task.

Dart ('47, and elsewhere) has insisted on the tool-using habits of the australopithecines from evidence at several sites of broken and seemingly utilized bones and broken skulls which exhibit signs of fracture and crushing. It is altogether possible, however, that the faunal assemblages at these sites represent the remains of kills by carnivores, particularly hyaenas, and are not the kitchen debris of these early, primitive hominids. There is still no unequivocal evidence to show that these creatures utilized or manufactured tools or weapons.

SUMMARY

The australopithecines of southern Africa are all of Lower Pleistocene age (table 3). The youngest member of the group, represented by the subgenus *(Paranthropus)*, lived during a late wet phase (stadial) of the first African (or Kageran) pluvial stage. An evolved stage of the Kafuan pebble-tool industry is known from riverine and lacustrine deposits of this age. An earlier variety of australopithecine, represented by the subgenus *(Australopithecus)*, lived at the onset of this wet phase and in an earlier drier phase probably corresponding to an interstadial of the Kageran pluvial stage. Tool-making was already known at this time in Africa as shown by the occurrence of less evolved Kafuan pebble-tool in riverine deposits in central and eastern Africa.

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A NOTE ON ANTI-Le^b AND REAGENTS PREDOMINANTLY REACTING WITH GROUP O CELLS

COMMENTS ON A PAPER BY MILLER, ROSENFIELD, VOGEL, HABER AND GIBBEL

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I should like to make a few comments on the statement nade by Miller, Rosenfield, Vogel, Haber and Gibbel ('54) hat "From the description of the two anti-Le^b sera employed n Grubb's study it would appear that the antibody activity n both was predominantly anti-O rather than anti-Le^b sera."

The principal serum used by me had the following properies (Grubb, '51): "It did not react with any blood from dults of group Le (a +). Its titre was 16. Its reactions with roup A$_1$ bloods were generally definitely weaker than with roup O and A$_2$ bloods. It was tested on donors from the panel of the Lister Institute and reacted like an anti-Le^b erum."

Anti-Le^b was originally described by Andresen ('48) in Denmark. The reactions of bloods from southernmost Sweden with the serum used by me gave frequencies practically dentical with those found by Andresen and co-workers with nti-Le^b serum (see table p. 77; Grubb, '51).

The serological properties of anti-H reagents have been epeatedly described (see, for example, Grubb, '49), and it s generally agreed that they react with more than 99.9% of roup O bloods. Watkins and Morgan ('55) state: "All roup O cells with the exception of the rare 'Indian' type f blood show reactivity with both anti-O and H-sera." In ontrast, anti-Le^b reacts with about 70% of group O bloods.

The anti-H and anti-O sera hitherto studied have no differential action on red cells from secretors and non-secretors.

The existence of some similarity between anti-H and anti-Le^{b} was early observed and considered by Grubb and Morgan ('49), and Grubb ('51). Indeed, it was this similarity that induced me to study whether there was any correlation between Lewis blood group and secretor character (Grubb, '48). Our paper (Grubb and Morgan, '49) stated "It was thought earlier that a very close relationship might exist between H-substance and Le^{b} substance and in consequence a number of specimens . . . were tested . . . . The results showed that H-substance and Le^{b} substance cannot be identical." This has since been confirmed (Annison and Morgan, '52). This similarity is thus not an identity.

The reactions of the serum studied by me (Grubb, '51) very nearly coincided with those expected for an anti-S (Secretor) serum and were thus in essence predicted long ago. I do not understand why such a serum should be designated anti-O. In all characters that can be compared it agrees with those of the original anti-Le^{b}. As is now well established, anti-Le^{b} does not detect all ABH-secretors when tested against red cells. Genes on other loci determine, at least partly, this non-reactivity of red cells from certain ABH-secretors, gene A_1 being one well established example.

As to the so-called anti-Le^{b} "Hir." extensively used by Miller, Rosenfield, Vogel, Haber and Gibbel ('54), it is to be observed that in contrast to Andresen's original anti-Le serum its reactions were not to any appreciable extent dependent on ABO groups and secondly that it was inhibited by salivas from most people with red cell type Le (a +). I appears questionable whether this serum should be designated anti-Le^{b}.

It is obvious that there are sera with similar properties which nevertheless differ somewhat in specificity. Confusion has been created by referring to all these sera as anti-Le The reactions of the sera type "Aagaard" (Brendemoen '50) are not yet properly understood.

If a revision of existing nomenclature (Andresen et al., '49) is to be applied, the change should be clearly defined.

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A BLOOD GROUP GENETICAL SURVEY IN COOK ISLANDERS, POLYNESIA, AND COMPARISONS WITH AMERICAN INDIANS[1]

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The Cook group consists of 15 small islands divided into two distinct groups with 7 islands in the Northern group, and 8 islands in the Lower or Southern group. Six islands of the Southern group and 5 islands of the Northern group are permanently inhabited. In land mass they total 100 square miles, scattered over an ocean area of approximately 850,000 square miles. The largest island covers 26 square miles, while the smallest is less than half a square mile. They all fall within the center of the Polynesian triangle and are located from 9° to almost 23° South latitude and from 156° to 167° West longitude. Their estimated total native population in 1953 was 14,978 of which 93% were estimated by the government to be ''pure'' or ''full-blooded,'' although a survey by one of us (E. I. F.) indicates that only 41% may be of unmixed origin.

The group was first seen by Captain Cook on his second voyage in 1773. Individual islands were found piecemeal by

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[4] The fieldwork carried out by one of us (E.I.F.) was done under the auspices of the United States Educational Foundation in New Zealand (Fulbright Fellowship). Grateful acknowledgment is made to the following individuals who materially aided in collecting and shipping the blood samples: R. Crocombe, P. Dixon, W. Kane, G. Leopold, Manea, T. T. Romans, Teariki, J. M. Staveley, and also special thanks to J. Numa for his generous assistance.

various explorers after Cook up to 1823. Strong European contact began with missionary activities in 1821 in the Lower Cooks, and about 1849 in the Northern group. The Cooks did not suffer the population decimation experienced by other Polynesian groups due to European contact, although their numbers were apparently greatly reduced. The earliest known population figure for Rarotonga is from 6,000 to 7,000 in 1823, which compares favorably with the 1954 estimate of 6,000. The lowest recorded figure for Rarotonga is about 2,500 in 1906. The approximate population figures for some of the other islands are as follows: Aitutaki 2,590, Mangaia 1,900, Atiu 1,300, Mauke 800, Manihiki 475 and Mitiaro 350. It should be noted that for generations there has been continuous island-to-island movement within both groups.

The Southern group islands are of volcanic origin, with fertile lowlands and hilly or mountainous interiors surrounded by coral reefs. The Northern islands are typical coral atolls with limited soil. Their exports reflect their topography, for the fertile Southern group exports oranges, tomatoes, copra and pineapples, while the barren Northern islands export only pearl shell and copra. The vast majority of Cook Islanders are primary producers, and export crops occupy only a secondary place in their economy.

The Cook Islands are administered by the Island Territories Department of the New Zealand government.

MATERIALS AND METHODS

The first lot of blood samples was collected without critical anthropological selection on Rarotonga from March 15–24, 1954, at the same time as a leprosy survey was made by the Cook Island Health Department. The second lot in which some attempt at selection was made consisted of samples collected on Rarotonga from June 5–21, 1954, and samples collected on Aitutaki, June 22–23. The individuals originated mainly on the 7 islands already mentioned with Rarotonga the best represented. The samples were all taken from adult individuals who, on preliminary questioning, were thought to be unmixed

Cook Islanders. A total of 308 blood samples was obtained, but of these 39 were discarded on arrival in Melbourne due to haemolysis. Refrigeration of samples during collection and transport was poor, transport arrangements presenting many difficulties.

The methods employed for collecting and testing the samples have been described again in detail by Simmons, Graydon, Semple and Taylor ('51).

RESULTS AND DISCUSSION

Results for individual islands have not been presented since the numbers in most cases were small, and there was no serological evidence of inter-island differences.

The results obtained for the A-B-O, M-N-S and Rh blood groups and gene frequencies are shown in table 1.

A-B-O groups. All of the 136 samples of group A and 6 of group AB were of subgroup A_1 and A_1B respectively. The frequency of gene *O* is approximately twice that of *A*, while *B* has a frequency of .039. A-B-O surveys in Polynesia prior to 1939 have been tabulated by Boyd ('39). Shapiro ('40) in 1934–1935 determined the A-B-O blood groups in 124 Polynesians at Tahiti, 176 in the Tuamotus, and 89 in the Australs, Rapa, Mangareva and Easter Island. A recent short review of blood groups in Polynesia was published by Graydon ('52). Blood group frequencies for New Zealand Maoris have been reported by Graydon and Simmons ('46) and by Simmons, Graydon, Semple and Taylor ('51). The blood groups of Kapingas, the Polynesian people of Kapingamarangi situated in Micronesia have been recorded by Miller ('50), and by Simmons, Graydon and Semple ('53).

From table 2 which shows the A-B-O frequencies in Polynesians a broad picture emerges which is moderately consistent for those groups regarded as least mixed. *O* is high as it is generally in Micronesia, Indonesia and Melanesia (Simmons, Graydon and Semple, '53). The Polynesians however, differ here from these other peoples in two aspects: *B* is zero, or of low value for a large part of Polynesia, while the *A* frequency

TABLE 1

A-B-O, M-N-S and Rh blood groups and gene frequencies in Cook Islanders

NO. TESTED	BLOOD GROUPS O	A$_1$	B	A$_1$B	GENE FREQUENCIES *A*	*B*	*O*
269	113 42.0%	136 50.6%	14 5.2%	6 2.2%	.314	.039	.647

	M	MN	N	*m*	*n*
269	95 35.3%	126 46.8%	48 17.8%	.587	.413

	No. S+	M S+	M S−	MN S+	MN S−	N S+	N S−	*ms*	*mS*	*ns*	*nS*
267	48 18%	3 1.1%	92 34.5%	28 10.5%	97 36.3%	17 6.4%	30 11.2%	.579	.011	.327	.08

	Rh$_1$Rh$_1$	Rh$_1$Rh$_0$	Rh$_2$	Rh$_1$Rh$_2$	R^1	R^2	R^0
267	71 26.6%	7 2.6%	63 23.6%	126 47.2%	.516	.459	.025

TABLE 2

A-B-O frequencies in Polynesians

LOCATION	AUTHORS	NO. TESTED	*A*	*B*	*O*
Tuamotus	Shapiro ('40)	176	.315	0	.69
Australs	Shapiro ('40)	33	.166	0	.83
Mangareva	Shapiro ('40)	29	.357	0	.64
Easter	Shapiro ('40)	21	.423	0	.57
New Zealand (Maoris)	Graydon and Simmons ('46)	267	.352	.004	.64
New Zealand (Maoris)	Simmons et al. ('51)	180	.338	0	.66
Kapingamarangi (Kapingas)	Miller ('50)	169	.242	0	.75
Kapingamarangi	Simmons et al. ('53)	46	.250	0	.75
Hawaii	Cited by Boyd ('39)	413	.382	.018	.60
Easter	Cited by Boyd ('39)	63	.472	.030	.50
Tahiti	Shapiro ('40)	124	.376	.039	.59
Cook Islands	Present survey	269	.314	.039	.64
W. Samoa	Cited by Boyd ('39)	51	.244	.100	.64
Am. Samoa	Cited by Boyd ('39)	500	.103	.118	.76

has an average value of about .3 which is higher than that found in Micronesia, Indonesia or Melanesia.

It would seem likely that when the early Polynesians dispersed in the Pacific they lacked group B because of its absence in widely scattered groups of people in the area. In Kapingas and in New Zealand Maoris, B is known to have been introduced, and genealogies have shown that in the former people, Micronesians or Europeans were mainly responsible, while in Maoris, Europeans were usually the source of the gene. In Hawaii and Tahiti its introduction has been attributed to known European or Mongoloid admixture. In Easter Island, although the series were small, B was found in one lot, and was absent in a group carefully selected by Shapiro. The Samoans with *B* frequencies of .100 and .118 most likely reflect direct Melanesian and Micronesian influence, and the *B* frequency is therefore an expression of geographical location as in Fijians, where $B = .106$. Similar influences may be expected to have extended into the Cook Islands, and these together with recent known European, Mongoloid and other admixture could readily explain the present frequency of *B*. Melanesian and Micronesian peoples would probably be the predominant sources of B, because of failure to demonstrate subgroup A_2, both in Cook Islanders and in Fijians.

It was stated earlier that one of us (E. I. F.) considers that only 41% of Cook Islanders may be of unmixed origin, so that the present frequency of B in these people is not surprising. Shapiro ('40) observed that unmixed natives in Polynesia were hard to find, and pointed out that they have never exhibited reluctance nor betrayed any inhibition against the freest kind of intercourse with sailors, traders or any visitors to their islands. This known admixture has been going on for over 150 years so that the introduction of genes not previously possessed by them or by their neighbors, must be expected, but these genes would generally be of low frequency in the present population, and certainly would not be as high as the B in Fiji, Samoa and the Cook Islands. However, one man of importance and power such as a new tribal chief or a

European, by producing many children in a small community, may introduce a new gene, and in a generation or two cause a marked change in the usual gene frequency pattern. A European amongst the Kapinga people caused such a change by introducing group B. The genealogies in this case were prepared by Dr. K. P. Emory of Honolulu during his extensive studies on these Polynesian people. It has been shown that B is absent over a large area of Polynesia, that it occurs in very low frequency in a few populations (where admixture is known), and that it shows a dramatic increase in frequency in the west near the Melanesian-Polynesian boundary. In this aspect of the discussion the authors agree with Shapiro ('40) who, after considerable travel and field work in Polynesia, expressed the view that B was introduced to Polynesians in the west mainly by their Melanesian and Micronesian neighbors, whom we know to be rich in the B factor.

The M-N-S types. Table 3 shows the M-N-S frequencies for Cook Islanders compared with those for New Zealand Maoris and Kapingas, which are the only M-N data as yet available for Polynesia. In each instance the *m* frequency is greater than .5 which is unusual for Pacific island peoples except for groups in the Philippines, Java and Borneo. Other peoples with high *m* are American Indians, Eskimos, Japanese, Chinese and Asian Indians. In Kapingas $m = .71$ which is the highest *m* frequency found to date in Indonesia, Micronesia and Polynesia. Although the number of subjects tested was small this suggests that a high *m* frequency may possibly be found in other Polynesian groups where admixture with low *m* populations is unlikely to have taken place. The S positive percentage is higher in the Cooks than in New Zealand, but its distribution in the two peoples is similar. The higher S percentage in the Cooks is compatible with Melanesian influence as suggested for the present *B* frequency there, but this influence does not explain the higher *m* in Cook Islanders than in Maoris. In the small sample of 46 Kapingas, S was not detected. If further samples can be obtained from this isolated

M-N-S frequencies in Polynesians and American Indians

POPULATION	AUTHORS	NO. TESTED	m	n	NO. TESTED	% S+	ms	mS	ns	nS
Cook Islanders	This survey	269	.587	.413	267	18.0	.579	.011	.327	.083
Maoris (N. Z.)	Simmons et al. ('51 and '53)	447	.503	.497	148	12.2	.500	.014	.438	.048
Kapingas	Simmons et al. ('53)	46	.71	.29	44	0	.70	0	.30	0
Blood Indians	Chown and Lewis (Mourant, '54)	241	.873	.126	241	61.8	.556	.317	.062	.065
British Columbia Indians	Chown and Lewis (Mourant, '54)	300	.770	.230	300	32.7	.611	.159	.209	.021
Navaho Indians	Ikin and Mourant (Mourant, '54)	97	.887	.113	97	44.3	.702	.185	.051	.062

TABLE 4

Rh frequencies in Polynesians and American Indians

POPULATION	AUTHORS	NO. TESTED	R^1 (CDe)	R^2 (cDE)	R^0 (cDe)	R^z (CDE)	r (cde)	r' (Cde)	r'' (cdE)
Cook Islanders	This survey	267	.516	.459	.025	...	...	...	...
Maoris (N. Z.)	Simmons et al. ('51)	180	.465	.486	.027	...	...	.022[1]	...
Kapingas	Simmons et al. ('53)	46	.75	.24	.01	...	...	...	...
Brit. Columbia Indians (Coastal)	Chown and Lewis (Mourant, '54)	256	.318	.607	.067	.008	...	...	...
Brit. Columbia Indians (Interior)	Chown and Lewis (Mourant, '54)	103	.282	.571	.148	...	...	...	...
Brit. Columbia Indians (Athapascan)	Chown and Lewis (Mourant, '54)	105	.345	.413	...	.026	.130	.086	...
Chippewa Indians Minnesota	Matson and Levine (Mourant, '54)	161	.337	.530	...	.020	.080	...	.032
Navaho Indians	Boyd and Boyd (Mourant, '54)	305	.326	.356	.069	.058	...	.172	.019
Navaho Indians	Ikin and Mourant (Mourant, '54)	97	.431	.277	.280	.013	...	...	...
Brazilian Indians	Pantin and Junqueira (Mourant, '54)	73	.586	.297	.066	.051	...	...	...

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[1] This may actually be an Rh_o variant (D^u) of "low grade." This may also apply to some of the examples of r' and r" found in American Indians. One $Rh_o(D^u)$ variant of "low-grade" was found in Cook Islanders.

people, confirmation of the S finding and additional serological tests on them would be of value.

The Rh types. The Rh gene frequencies for Cook Islanders, Maoris and Kapingas are shown in table 4. Again it is found as it was for A-B-O and M-N that the Polynesian Rh frequencies by their higher R^2 and lower R^1 are quite distinct from those tabulated for Micronesia, Indonesia, and Melanesia by Simmons and Graydon ('51) and by Simmons, Graydon and Semple ('53). The Polynesians in the Pacific it seems are a distinct people, and of those serologically tested, the Maoris of New Zealand appear to be the least mixed or blended with other races. On the basis of blood group distribution the Australian authors have recorded Polynesian influence apparently extending into New Caledonia, Loyalty and Pine Islands (Simmons, Graydon, Avias and Williams, '49), Fiji (Simmons, Graydon and Barnes, '45; and Simmons and Graydon, '47), Gilbert Island (Graydon, Simmons, Semple and Ingram, '53) and possibly Truk (Simmons, Graydon and Semple, '53). Kapingamarangi in Micronesia has a Polynesian population, some of whom have recently migrated to Ponape. It seems likely that a two way flow has been going on, in and out of Polynesia for many centuries, particularly in the west with Melanesia and Micronesia. It is unfortunate that to date we have failed to get blood samples from selected people in eastern Polynesia due mainly to isolation and transport difficulties.

Other observations on Cook Islanders. Table 5 presents observations on Cook Islanders, Maoris (N. Z.) and Kapingas relative to $\mathrm{Rh}^{o}(\mathrm{D}^{u})$ variants, $\mathrm{rh}^{w}(\mathrm{C}^{w})$, P, Lewis, Duffy and Kell blood groups. P. T.C. taste reactions are also recorded. One "high-grade" Rh_o variant was found in 267 Cook Islanders. None was found in 153 Maoris (N. Z.) although one example may have been present. The individual, an aged woman, died, and a further sample could not be obtained for testing by the anti-globulin technique. No examples of $\mathrm{rh}^{w}(\mathrm{C}^{w})$ were detected in the 3 series, nor has this gene been found in Pacific peoples to date.

Blood group P. There is wide variation in the percentage of P positive reactors in the three groups with Maoris reaching a reported figure of 90.2% P positive. The Maori tests and others performed at the same time were carried out with an anti-P serum of group AB which was shown subsequently to have a weak anti-A_1 content. This extra agglutinin was responsible for trace reactions at 5°C., all of which were classed as P positive. The control positive and negative cells used for these tests were unfortunately of group O, so that the significance of the trace reactions was not realized at the time. Staveley ('52) of Auckland advised us that he had tested 73 Maoris and found 40, 55% to be P +. It is considered that this P percentage may be close to the true figure for New Zealand Maoris. Thus we find the P + reactivity in Cook Islanders to be 45.7%, in Maoris of N. Z. probably 55%, and in a small series of 18 Kapingas 67%. From the figures for Cook Islanders and Maoris it is likely that the Polynesian P + percentage will average about 50 when more groups are tested.

Blood group Lewis (Le^a). There were 17.2% $Le^{(a+)}$ in Cook Islanders compared with 29% in Maoris and 49% in Kapingas. No A, B or H salivary secretion tests were carried out on Cook Islanders, but tests made on Maori salivas for A or H secretion showed almost complete correlation with the $Le^{(a+)}$ figure of 29%.

Blood group Duffy (Fy^a). In the Cook Island series 234/254, 92.1% were Fy(a+), while in Maoris (N. Z.), 38/53, 71.7% were Fy(a+). The Maori results were given in the Micronesian report by Simmons et al. ('53), and the tests were performed on samples 5–8 days old, and also on other samples 12 months old. The old samples were taken at random from stored cells while the fresher samples were taken from Maoris living in one locality. This may explain the wide variation of results obtained in the two small series because they were considered to be technically accurate at the time. Dr. J. M. Staveley has advised one of us (R. T.S.) that he

TABLE 5

Summary of other tests performed on Polynesians

POPULATION	Rho (D^u) VARIANTS	rh^w (C^w)	P+	Le(a+) Lewis
Cook Islanders	1/267 .4%	0/267 0%	117/256 45.7%	44/256 17.2%
Maoris N. Z.	0/153 0%	0/153 0%	138/153[1] 90.2%	49/169 29%
Kapingas	0/46 0%	0/46 0%	12/18 67%	20/44 45%

	Fy(a+) Duffy	K Kell	P.T.C. REACTIONS TASTERS
Cook Islanders	234/254 92.1%	4/254 1.6%	180/215 83.7%
Maoris N. Z.	38/53 71.7%	Present, low	144/157 91.7%
Kapingas	...	...	39/54 72%

[1] The Maori P positive percentage is probably about 55 as found by Dr. J. M. Staveley of Auckland, New Zealand. (Staveley, '52.)

TABLE 6

P.T.C. taste reactions

POPULATION	AUTHORS	NO. TESTED	PER CENT TASTERS
Ainu-Japanese	Simmons et al. ('53)	175	94.8
Thais	Simmons et al. ('54)	56	94.6
Ainu	Simmons et al. ('53)	328	93.6
Maoris	Simmons et al. ('51)	157	91.7
New Hebrideans	Simmons et al. ('54)	196	90.8
Cook Islanders	This survey	215	83.7
Trukese	Simmons et al. ('53)	126	81.7
Palauans	Simmons et al. (53)	198	78.8
Kapingas	Simmons et al. ('53)	54	72.0
Chenchu	Simmons et al. ('53)	132	62.1
New Guinea Natives (Mt. Hagen)	Semple et al. (unpublished)	179	54.2
Australian aborigines	Simmons et al. ('54)	152	50.7

found 58/70, 82.9% of Maoris to be Fy(a+). Polynesians as represented by Cook Islanders and Maoris are thus again distinct from other Pacific peoples in that their Fy(a+) percentage varies from 71–92% while most Pacific races are approximately 100% Fy(a+). The higher Duffy percentage in Cook Islanders compared with Maoris may be due to the postulated Melanesian influence, as Melanesians are 100% Fy (a+). Small numbers of fresh and also stored blood samples of other races were also tested when supplies of Duffy testing serum became available. Some blood samples had been stored at 5°C. in glucose-citrate solution for periods up to 16 months. Results were presented for 11 racial groups most of whom were 100% Fy(a+). Duffy tests performed by Kooptzoof and Walsh ('54) have confirmed these results for a number of Pacific peoples, and have also shown in large numbers of tests that other Pacific races are also 99–100% Fy(a+). The Duffy antigen like a number of other blood group antigens has therefore been proved to be an extremely stable antigen in blood stored under satisfactory conditions.

Blood group Kell (K). Four individuals in 254, many of whom were not selected anthropologically, were shown to possess the K antigen. Two of the four are regarded as being of mixed blood, one was suspected at the time of blood collection, while the other was found to be suspect as the result of further examination and questioning. In several other instances possible evidence of admixture has been found on subsequent examination, but the persons concerned have not been removed from the series because of the probable high incidence of undected admixture mentioned earlier in the text. In 4 of 7 persons listed below admixture was suspected only after the blood grouping tests had been completed, either as the result of the blood tests, or on physical grounds. As the Cook Islanders are considered to be so mixed, the present sampling represents a partly selected cross-section of the population today.

The following data are given for 7 individuals to show the possible association of a particular blood antigen and admixture:

No. 1	Kell positive.	Part European a long while ago.
No. 10	Nothing unusual found.	Part European several generations back.
No. 35	Nothing unusual found.	Part Chinese.
No. 70	Kell positive.	Part Martinique Negro.
No. 81	Group A_1B.	Part European.
No. 98	Nothing unusual found.	Part Oriental.
No. 350	Group A_1B.	Part Oriental.

It has been demonstrated that two of four individuals shown to be Kell positive could be discarded from the series because of some evidence of admixture. It seems reasonable to believe that the Kell antigen has been introduced to the Cook Islanders by admixture with other races. There is unpublished evidence that the Kell antigen is also present in low frequency in New Zealand Maoris as it has been detected by one of us (R. T.S.) and by Dr. J. M. Staveley. The data however, are insufficient to assess the significance of the findings. More information on the Kell antigen in the Pacific is required.

P.T.C. taste reactions. A summary of P.T.C. taste reactions reported by the Australian authors are given in table 6. Other extensive P.T.C. data have been tabulated by Montagu ('51), page 271 and by Boyd ('50) page 280. At the moment our main interest lies with Maoris and Cook Islanders. In Maoris 91.7% are tasters, but in Cook Islanders the percentage has dropped to 83.7 which may be due to Melanesian or Micronesian influence, although sufficient data are lacking to date for Melanesians. Maoris, Ainu, Ainu-Japanese and Thais all have more than 90% tasters, and reference to Montagu's table shows that groups with 90–98% tasters include American Indians at Montana, Alberta, Kansas, Northern Alberta and Ramah, New Mexico. Other groups are American and African Negroes, Japanese, Chinese and Formosans. Thus the Polynesians share with American Indians and the Mongoloid peoples generally, an extremely high percentage of P.T.C. tasters, and in this respect they differ from people in most other racial groups except Negroes. The difficulties encountered in assessing P.T.C. taste reactions in primitive peoples, and hence possible inaccuracies in results, need hardly be mentioned again. The results shown in table 6 would seem to indicate that P.T.C. taste tests are worth including in all racial surveys.

POLYNESIANS AND AMERICAN INDIANS

It is felt that some comparisons of blood group gene frequencies for Polynesians and American Indians should be made in this paper, and some of the relevant literature summarized.

Laughlin ('51) in the "Introduction" to "The Physical Anthropology of the American Indian" (Fourth Viking Fund Summer Seminar) said:

> "New forms of evidence, such as the blood groups and dentition, provide useful additions to our tool kit. For many of the other newer genetic characters there are as yet insufficient comparative data but they will be available in the future. At present it is possible to characterize American Indians and to demonstrate their primary affiliation with Asiatic Mongoloids solely on the frequency of genetic characters without resort to descriptive morphology."

Birdsell ('51) who discussed "The Problem of the Early Peopling of the Americas as viewed from Asia," said as part of his conclusions:

> "The reconstructed patterning of peoples in Eastern Asia, as well as the scanty archaeological evidence, suggests a dihybrid origin for the American Indians. The two racial elements present at the proper time and place for the peopling of the New World were Amurians and Mongoloids."

Amurians according to Birdsell refer to a proto-Caucasian population ancestral to living Ainus and Murrayians.

Boyd ('51) in his paper presented at the same meeting and entitled "The Blood Groups and Types" pointed out in relation to Indian A-B-O groups that:

> ". . . the general picture of South America is a more or less pure group O population with a small mixture of group A amounting to about 5%." . . . "In Mexico the picture is almost complete O with A and B creeping in as the percentage of white mixture becomes higher." . . . "In North America we find two and probably three layers of immigration represented. In the southern and eastern regions we find

evidence of Indians who were mostly blood group O, but who possessed some blood group A." . . . "A fairly typical picture is probably the 361 Navaho Indians tested by Boyd and Boyd near Ramah, New Mexico, where they found 76.7% O, and 23.3% A, and no B or AB. Such Indians are common in the Southwest and probably were once common in parts of the West and Middle West." "As we go further North, however we meet another type of population. This is a population which consists of O and A, with no B except small amounts probably due to white admixture, but with the A as frequent as the O or in some cases greatly in excess . . . Such populations are represented by the Bloods and the Blackfeet studied by Matson."

[Mourant ('54) cites three other recent Indian surveys as follows:

In British Columbia (Chown and Lewis) O = 81%, A = 18% with a trace of B,

Chippewa Indians (Matson and Levine) O = 88%, A = 12%, and a further small series of Navaho Indians, New Mexico (Ikin and Mourant) with the same results as found by Boyd and Boyd.]

In relation to the M-N and Rh types, Boyd said:

". . . the M and N frequencies for all the Americas are much more alike than are the A and B frequencies. All the American Aborigines agree in having very little of the gene N and a high frequency of the gene M." . . . "From the standpoint of Rh, American Indians are typically Asiatic, and if the Rh genes had been investigated before the AB, M and N, no question would have arisen about the value of blood-grouping genes in determining racial origins." . . . "The American Indians reflect fairly accurately the Rh configuration of the Asiatic and Pacific population, and we know they must have been derived by descent from such populations."

Heyerdahl ('52) following the Kon-Tiki raft voyage produced a volume of 821 pages entitled "American Indians in the Pacific." He discards the theory that Polynesians originated in Malaysia and migrated thousands of miles against wind and current before they eventually reached their present home in the islands facing America. He does not deny the origin of this people somewhere on the coast of the Western Pacific, but claims they reached their present home by an infinitely longer coastal journey out of the Old World Stone Age through the extreme Northern Pacific to the Northwest Coast of America. He suggests that one migratory stream drifted from the Northwest Coast (Canada) with the current to Hawaii and thence to New Zealand. He demonstrates the complexity of Polynesian race and culture, and claims that before the arrival of this originally Asiatic stock, an earlier culture-people had already settled Polynesia from pre-Inca Peru sailing into the Pacific on balsa rafts with wind and current via Easter Island to their eventual island homeland. He discusses the Indians of the British Columbian coast, and claims affinity between them and their Hawaiian neighbors on the grounds of stature, colour, features, craniology, blood groups, tools, implements, customs, beliefs and traditions. The ease of a drift voyage in the coast current he claims makes the affinity all the more probable. He claims to demonstrate traces of Caucasian-like elements both in Polynesia and in pre-Inca Peru, and points to records of aboriginal Peruvian navigation in the East Pacific on balsa rafts, he points also, to analogies between the cultural products, customs and mythology of the two areas.

The only aspect in which the present authors are directly interested is that of blood groups. Heyerdahl's statements on blood groups were made at a time when only A-B-O data were available for certain Polynesian peoples, and after examining this material he comments as follows:

> "Later studies by Boyd ('39) and many others have revealed that group B reaches its world maximum in India, being high throughout Eastern Asia, including Indonesia, and even right into Melanesia and Micronesia. A clear break is marked at the border of Polynesia, where B drops to a minimum, or is absent. Only on the extreme western margin of Polynesia, bordering directly on Melanesia and Micronesia, both high in B, is there any impressive evidence of B. Further away, as in the Tuamotus and Easter Island, the B factor is conspicuous by its total absence. At present it is sufficient to stress that this racial factor, considered to be one of the most dependable factors in a study of inheritance, speaks strongly against a Polynesian descent from Malays, or from any other Indonesian stock. It would be forcing a favourite doctrine against better evidence to ignore the strongly marked serological demarcation line which

severs the Polynesians east of Samoa from the Melanesians, Micronesians, and Indonesians to the west of this line. The quite extraordinarily low percentage of blood group B in Polynesia, indicating an original purity of only O and A in this domain obtains no satisfactory explanation from a theory of Malay or Indonesian descent."

Other references to blood group evidence in the text supporting his thesis refer only to the A-B-O blood groups for the island peoples of the Pacific, and to American Indians. The following statement is made relative to Indians of the Northwest American coast:

"The general result of the various blood samplings on the Northwest American coast, as listed by Boyd ('39, p. 162), is to show that the Northwest Indians possess a dominance of O, a strong content of A, but hardly any B or AB. With O the principal blood group factor, the Kwakiutl and Northwest Indians have up to a maximum of nearly 40% A; and yet, generally, no B rising to a maximum of 2.4% B; with no AB in any samplings. These Northwest Indian data correspond as closely to the serological facts concerning Polynesian islanders as to those of their own North American relatives of the same mainland. With a definite and unchangeable characteristic in the B and AB factors, which are kept at a constant level at or near zero, North American and Polynesian tribes both display some variety in the relative dominance of the O and A. In some tribes like the Blackfeet and Blood Indians of North America, and the Easter Islanders and Hawaiians of Polynesia, the A factor outbalances the O, reaching 60% or more; whereas in others, like certain Kwakiutl and Tsimsyan Indians of Northwest America, and the Maori and Tubuai islanders of Polynesia, the A is limited to 30–40% or less. Thus the New Zealand Maori is even closer in blood types to the Northwest Indian Kwakiutl than to his own known relatives in Tahiti or Hawaii. And as a general rule it may be said that, as far as the blood groups are concerned the Polynesian people as a whole fall in entirely with the known facts from the particular groups of Yellow-brown people that have settled the northwestern part of North America, both inside and adjacent to the actual Northwest Coast Territory."

Graydon ('52) utilizing the available blood group data to the middle of 1951 made comparisons in the A-B-O, M-N and Rh blood groups systems between New Zealand Maoris, Ute and Mexican Indians, and the peoples of Melanesia and Indo nesia. Graydon plotted the A-B-O data using triangular co-ordinates, and as a result said:

> "Clearly the Polynesian is closer to the American Indian than to either the Melanesian or Micronesian in respect of A, B, O groups."

From an examination of a diagrammatic summary of relevant M-N frequencies he said:

> "Again one can find nothing to favour either the Melanesian or Micronesian routes, for the M, N frequencies in Melanesia and Micronesia are similar yet quite unlike those in the Maoris. When opportunity offers we hope to test other Polynesian groups, and it might be expected that the frequency of m will be higher than in the Maoris."

(In the present paper it is shown that m in Maoris $= .503$, m in Cook Islanders $= .587$ and in the small series of Kapingas $m = .71$.) From an examination of the Rh gene frequencies he made this observation:

> ". . . the pictures presented by Maoris and the American Indians are strikingly similar and both are remarkably unlike those of the Melanesians and Micronesians. The frequency of gene R^1 is much lower and of R^2 much higher in the Polynesian and Amerinds than in the Melanesians and Micronesians. This offers further strong serological argument in favour of an affinity between the former pair."

He concludes his paper by saying:

> ". . . it is submitted that the serological evidence presented in this paper supports a Polynesian-Amerind relationship, making it probable that the islands of Polynesia have been settled largely by migrations from continental America."

In Graydon's paper there is a warning which might well be quoted as it is important to remember when gene frequency comparisons are being made. It is as follows:

> "Where gene frequencies are low, chance plays a big part in whether or not they will be detected in a series of tests. Consequently arguments based on comparisons of very low gene frequencies must be treated with reserve."

Mourant ('54) has briefly commented on the origin of the Polynesians and some of his remarks are as follows:

> "The fact that the Polynesians share amongst themselves a common characteristic ABO constitution different from that of other Pacific islands, is in accord with their probable recent emergence as a distinct 'race': though the different island populations are widely separated

they have not had time to develop divergencies from their original highly characteristic ABO picture.'' . . . ''Heyerdahl has shown from early records that fair-bearded men were present in South America before the time of Columbus. He has made a strong case for their having sailed to Polynesia, but he has not shown clearly how or whence they came to America. He favours the view that they were of European origin.'' ''The other main contributors to the peopling of Polynesia are said to have arrived later and to have been American Indians from the west coast of Canada — indeed they are positively identified as members of the still-existent Kwakiutl tribe." . . . "The Kwakiutl are a well defined people and we know much about their blood group composition and that of other neighbouring tribes.'' . . . ''The hypothetical immigrants from South America, on the other hand, cannot be compared to any population at present living in South America. Their supposed European or North African origin is rather too vague to be helpful but at least it can be assumed that in their wanderings through South America they acquired some American Indian genes. Thus we may seek, in the Polynesians American Indian genes from two sources, and the more localised Kwakiutl characters from one of these.'' . . . ''The closest point of resemblance between Polynesians and Americans lies in their Rh blood groups. North and South American Indians, Eskimos and Maori, unlike any other known race, have consistently high frequencies, usually a little under 50%, of each of the chromosomes CDe (R1) and cDE (R2). In the Maori and in the coastal tribes of British Columbia cDE is actually in excess of CDe. Other chromosomes are relatively rare in both American Indians and Maori. Many American populations have several per cent of CDE (Rz); this has not yet been found in the Maori but on the small numbers tested this cannot be counted as a discrepancy.'' ''Throughout America we find very high frequencies of the M gene, averaging about 80%. The Maoris have only 50% of this gene, but this is very much more than any non-Polynesian Pacific islanders possess. The small sample of inhabitants of Kapingamarangi with 75% is strictly comparable with the Americans.'' . . . ''The North American Indians are almost completely lacking in B but, unlike the South Americans, have a definite amount of A in addition to O. The Kwakiutl have an average A gene frequency of 8.5%, but there are highly significant differences between different samples tested, one showing 22% of A genes. Other neighbouring tribes have higher frequencies of A than Kwakiutl, and only a few hundred miles inland the Blackfeet and Blood Indians have 50 to 60% of A genes and are amongst the few known peoples who have more A than the Polynesians.''

Mourant then adds:

> "Observations on the ABO, MNS and Rh blood group systems are therefore all consistent with the theory of Heyerdahl. The results of tests for the other blood group systems in America are not sufficiently uniform to allow detailed comparison with the Polynesians." . . . "The Maori and North American Indians agree in showing very high frequencies of tasters of phenylthiocarbamide, but while the Maori have a rather high frequency of non-secretors of ABH, the American Indians have a high frequency of secretors. Thus it may be said that a large part of the genetic constitution of the Polynesians can be accounted for on a basis of an American, and especially a north-west American origin, but there must have been a considerable amount of mixing with other peoples, presumably the islanders to the west, to account for MNS and secretion frequencies. Even if the hypothesis of migrations from America to Polynesia should prove untenable there would still be a strong suggestion that Polynesians and North American Indians had in the not very distant past received many genes from a common pool."

The M-N-S frequencies for American Indians to date have been compiled by Mourant ('54) on pages 363–364, the Rh frequencies on pages 380 and 386–387, blood group P page 368, Lewis (Le^{a}) page 406, Duffy (Fy^{a}) page 409 and Kell (K) on pages 404–405. These may be compared directly with the blood groups and frequencies given in the present paper.

The S percentage is much higher in three groups of Indians (table 3) than in three lots of Polynesians. In Polynesians S is more frequently associated with type N, while in Indians S appears to be mainly associated with type M, the most prevalent gene being m. More data are obviously needed. As already pointed out the broad picture which emerges from an examination of the Rh frequencies (table 4) for most American Indian populations is generally the higher frequency of R^2 (cDE) as compared with R^1 (CDe). This aspect which is so unusual amongst most of the world's populations is further evidence of a genetic link between Polynesians, American Indians and Eskimos. The Polynesians possess the genes R^1, R^2 and R^{o} (cDe) while most American Indians have in addition the gene R^z (CDE). It is doubtful from an examination of most of the series tested to date whether unmixed American

Indians possess the genes r (cde), r' (Cde) or r'' (cdE). Th
alleged presence of these genes in some series may be due t
white admixture, to the presence of an Rh$_o$ (D^u) variant, t
poor samples, or to technical errors in testing. Further wor
is required to resolve the significance of the odd findings, fo
example the results obtained in two series of Navaho Indian
indicates the need for retesting this group. Mourant ('54) ha
shown that these people have "low-grade" Rh$_o$ (D^u) variants
A broad picture has emerged, but the detailed picture for bot
American Indians and Polynesians will require many mor
and closely controlled series of tests. In making these com
ments no criticism from the Australian authors is implied, fo
we have shown recently that the high frequency of the gene
(Cde) reported in Australian aborigines is due mainly to Rh
(D^u) variants in this race. The initial report was ours! A
the present time the blood groups P, Le^a, Fy^a and K offer littl
scope in a comparison of American Indians and Polynesians
The present authors consider the two main groups of Poly
nesians tested to be about 45% and 55% P+ respectivel
(table 5). In Indian populations tested P+ ranges from abou
41 to 85%. The P+ percentages are as follows: Mexican In
dians 79%, Wiener et al. ('45); Brazilian Indians 41%, Panti
and Junqueira ('52); Diegueño Indians 57%, Pantin and Kall
sen ('53); Blackfoot and Blood Indians 85% (estimated)
Chown and Lewis ('53); Chippewa Indians 84.5%, Matson
Koch and Levine ('54).

In Maoris (N. Z.) 29% were Le(a+) and there was clos
correlation between Le^a and A, B or H salivary secretion. I
Cook Islanders 17% were Le(a+). In Ute Indians of Uta
(Matson and Piper, '47) all of 79 were secretors of A or
substances while in Navahos 68 out of 69 were secretors (Boy
and Boyd, '49). Chown and Lewis (loc. cit.) found all of
Blackfoot and all of 241 Blood Indians to be Le(a—), that
all of them could be expected to be secretors. More data ar
needed, but in terms of the blood group Le^a and salivary secr
tion, the Polynesians and American Indians present differe
characteristics. This could be an important basic differen

in the two groups, but it may also be due to an added racial component in the Polynesians, or to loss of the non-secretor gene (*s*) during isolation in the same way in which the *A* gene is thought to have been lost, over large areas of the American continents.

Not sufficient is known of the blood group K distribution for even minor comment. The Fy^a blood group is of more interest because while all the Pacific island peoples are essentially 100% Fy(a+) the Polynesian percentage ranges from 70% to 92% in the Maoris and Cook Islanders respectively. In Indians in four surveys Fy(a+) ranges from 89.7% to 98.1%. This drop from 100% as shown in one Eskimo survey and in Mongoloids may simply indicate white admixture, but if it is real, it indicates another point of similarity between Polynesians and American Indians.

It may be said that the conclusions reached by Heyerdahl relative to American Indians and Polynesians on the basis of A-B-O blood groups only have not been contradicted by Graydon utilizing three blood group systems for comparison, or by Mourant who compiled all the available blood group data to the end of 1953. The blood groups and gene frequencies presented here for the Cook Islanders do not invalidate the conclusions reached, that there is a close blood genetic relationship between American Indians and Polynesians, and that no similar relationship is evident when Polynesians are compared with Melanesians, Micronesians and Indonesians, except mainly in adjacent areas of direct contact.

SUMMARY

The results of a blood genetical survey in 269 Cook Islanders of Polynesia are reported. The blood groups determined were A_1-A_2-B-O, M-N-S, Rh, P, Le^a, Fy^a and K. P.T.C. taste tests were also carried out.

The present sampling represents a partly selected cross-section of the population today. It is thought from field observations that less than one-half of the Cook Islanders are of unmixed blood.

The Cook Island blood groups when examined in association with those of New Zealand Maoris and Kapingas indicate that the Polynesians are serologically a distinct race amongst the Pacific island peoples. Differences in blood group frequencies between the Cook Islanders and Maoris (N. Z.) are consistent with Melanesian influence on the Cook Islanders.

As it is generally accepted that an affinity exists between American Indians (in their diversity) and Mongoloids, it is submitted on the basis of the Polynesian serological data presented and discussed here that the affinity must also include Polynesians, for at least the three peoples possess a major and basic common component. Serologically there is no evidence of any general Polynesian affinity with Melanesia, Micronesia or Indonesia, except mainly in adjacent areas of direct contact.

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THE BLOOD GROUPS OF THE HOTTENTOTS

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INTRODUCTION

The Bushmen, Hottentots and a few other small population groups in southern Africa have in common a number of cultural and physical characters in which they differ from the rest of the dark-skinned races of Africa including the very numerous Bantu speakers. They have, indeed, been regarded by some anthropologists as constituting a major sub-division of the human race, the Khoisan.

A serological study of the Bushmen (Zoutendyk, Kopeć and Mourant, '53) has shown that their blood group picture as a whole does not differ greatly from that of most Negro populations, and that they share those peculiarities in the frequencies of the MNS, Rh and Duffy blood groups which, taken together, differentiate Africans south of the Sahara from all other known human populations. The Bushmen have one of the highest known frequencies of the typically African cDe (R_0) chromosome of the Rh system and in this they resemble the Northern Nilotes (Ikin, Mourant and Roberts, '55) who, morphologically, differ from them to an extreme degree.

It was, therefore, important that the blood groups of the Hottentots should be examined, and the task was becoming an urgent one because of the small and diminishing numbers of this race. Hitherto, only their ABO groups had been examined (Pijper, '35); and it is now thought that the groups of the ABO system convey less information of far-back origins than do, for instance, those of the Rh and MNS systems (Mourant, '54). Following repeated attempts, it has at last become possible to carry out full blood-group tests on over 200 Hottentots, or nearly 1% of the known survivors.

MATERIALS AND METHODS

Through arrangements kindly made by Mr. J. Neser, Secretary for South-West Africa, and Dr. C. Hunter, Medical Officer to the Administration, specimens were collected by venepuncture from over 200 Hottentots in a number of their Reserves in South-West Africa by Mr. A. P. S. Albertyn, Senior Health Inspector. We are indebted to him not only for collecting them but for the selection of the individuals concerned, and for the prompt despatch of the specimens by air to Johannesburg. All persons tested were, as far as could be ascertained, of pure Hottentot descent, and records have been kept of their origin, sex and age which varied from 14 to 70 years. All this could not have been done without the keen cooperation and detailed local knowledge of Mr. Albertyn.

The specimens appeared to be in good condition on arrival and all were tested within 5 days of being collected. Tests were carried out with anti-A, -B, -C, -D, -E, -M, -N, -S, -Henshaw, -P, -Fy^{a}, -Kell, -Le^{a}, -Le^{b}, and -Lu^{a}. Most of the tests were performed by direct agglutination in tubes at the optimum temperature previously ascertained for each serum. The tests with anti-Kell were done by means of the indirect antihuman globulin test. The anti-C serum used was known also (as is usually the case) to agglutinate C^{w}-positive cells; all specimens positive with this serum were further tested with pure anti-C^{w}, with negative results in every case.

The single sample which on first testing appeared to be D-negative was tested for the D^{u} antigen by an indirect antiglobulin test with a strong "incomplete" anti-D with negative results. Dr. S. B. Griffiths kindly tested all the samples for sickling by means of the Sodium Hydrosulphite method of Williams and Mackey with negative results.

RESULTS

Gene frequency calculations were performed by the methods described by Mourant ('54). The results of the tests and calculations are shown in tables 1 to 5. In table 5 the gene frequencies of the Hottentots are compared with those of the Bushmen and of the South African Bantu.

TABLE 1

The ABO blood groups of the Hottentots

GROUP	NUMBER OBSERVED	FREQUENCY OBSERVED	FREQUENCY EXPECTED	EXPECTED NUMBER
O	79	0.3709	0.3796	80.85
A	69	0.3239	0.3140	66.88
B	52	0.2441	0.2339	49.83
AB	13	0.0610	0.0725	15.43
Total	213	0.9999	1.0000	212.99

Gene frequencies

O	0.6161
A	0.2167
B	0.1672
Total	1.0000

TABLE 2

The MNS and Henshaw blood groups of the Hottentots

PHENOTYPE	NUMBER OBSERVED	NUMBER HENSHAW POSITIVE	FREQUENCY OBSERVED	FREQUENCY EXPECTED	NUMBER EXPECTED
MMS	27	7	0.1343	0.1594	32.04
MsMs	86	1	0.4279	0.3827	76.93
MNS	24	10	0.1194	0.0921	18.50
MsNs	46	2	0.2289	0.2963	59.55
NNS	2	1	0.0100	0.0122	2.45
NsNs	16	0	0.0796	0.0573	11.52
Total	201	21	1.0001	1.0000	200.99

Chromosome frequencies

MS	0.1177
Ms	0.6187
NS	0.0243
Ns	0.2394
Total	1.0001

A brief preliminary account of the results was presented to the International Congress of Blood Transfusion in Paris in 1954. The ABO frequencies found by us agree closely with the observations of Pijper. The combined results of the two series of tests show an A gene frequency similar to that of the Bushmen, but that of the B gene considerably exceeds that of the Bushmen as well as of all known South African Bantu populations.

TABLE 3

The Rh blood groups of the Hottentots

PHENOTYPE	NUMBER OBSERVED	FREQUENCY OBSERVED	FREQUENCY EXPECTED	NUMBER EXPECTED
CCDee	7	0.0333	0.0363	7.62
CcDE	10	0.0476	0.0224	4.71
CcDee	56	0.2667	0.2860	60.05
ccDE	14	0.0667	0.0919	19.29
ccDee	122	0.5810	0.5589	117.37
ccddee	1	0.0048	0.0046	0.96
Total	210	1.0001	1.0001	210.00

Chromosome frequencies

CDe	0.1905
cDE	0.0589
cDe	0.6830
cde	0.0677
Total	1.0001

TABLE 4

The Lutheran, Kell and Duffy blood groups of the Hottentots

NUMBER TESTED	Lu(a+)	Lu(a−)	Kell+	Kell−	Fy^{a}+	Fy−^{a}
201	0	201	10	191	56	145

The frequency of the M gene is the highest known in Africa and represents the most marked departure of the Hottentots from the general African blood group picture. The Bushmen also, however, have a rather high M frequency as compared with other Africans. The frequency of the S gene is rather low and, as in the Bushmen, it mainly accompanies M. In both these populations the ratio of Ms and NS is higher than in Africa generally.

The frequency of the Henshaw gene in the Hottentots is one of the highest known. In West Africans and in Bushmen (in whom the total frequency is low) the Henshaw gene mainly accompanies NS, in the Hottentots it mainly accompanies, and is presumably closely linked to, MS. Recent work, including the present investigation, continues to show the Henshaw

TABLE 5

Comparative table of blood group gene frequencies
(Percentages to nearest whole number)

	HOTTENTOTS[1]	BUSHMEN[2]	S. AFRICAN BANTU[3]
O	61	74	69
A	21	20	19
B	19	6	12
MS	12	7	9
Ms	62	52	49
NS	2	2	4
Ns	24	39	38
Henshaw	5	2	3
CDe	19	9	14
Cde	0	0	2
cDE	6	2	1
cDe	68	80	60
cD^ue	0	9	0
cde	7	0	23
Lu^a	0	0	3
Lu^b	100	100	97
K	3	5	0.3
k	97	95	99.7
Fy^a	15	8	6
Fy^b	85	92	94

[1] From present investigation and Pijper, '32.

[2] From Zoutendyk, Kopeć and Mourant, '53 and Pijper, '35.

[3] ABO, Henshaw: Zoutendyk, A., unpublished data. Rh: Zoutendyk, A., '47. Lu, K, Fy: Shapiro, M., '52, '53; MNS, Shapiro, M. Personal communication, '53, quoted by Mourant, '54.

gene to be mainly confined to peoples of African origin, bu interesting variations are beginning to show in its connection to the other genes of the MNSs system, and it may be that significant pattern will soon emerge.

The Rh blood groups of the Hottentots show a typically African picture, but a less extreme one than the Bushmen The cDe chromosome frequency of 68% is considerably abov the African average but much lower than the 80% found i Bushmen. The relatively high frequencies of CDe and cDE resemble those of the northern Negroes rather than those o the Bantu of South Africa.

In both the Hottentots and Bushmen the frequency of th Kell gene is near the low level found in Europe, while th Lutheran gene appears to be absent. In Negroes, on the other hand, the Lutheran gene approaches the European frequency of 4% while Kell is very rare indeed.

As it is impossible to assess with confidence the results o tests with anti-P and anti-Le^{a} and Le^{b} when used on specimens of blood several days old we have not included detailed figures but on the results obtained the Hottentots, in contrast to Negroes generally, have a low frequency of P. They also show a low frequency of both Le^{a}- and Le^{b}-positives as do the Bushmen, and though to a less extreme degree, Negroes generally The frequency of the Fy^{a} gene is low as in Bushmen and Negroes.

Thus both Bushmen and Hottentots show an essentially African picture and, while it is true that both tend to deviate in the same directions from the African average, the deviations are not consistent since, for example, the Hottentots are the more extreme with respect to MNS but the Bushmen for Rh.

It has already been said (Zoutendyk, Kopeć and Mourant '53) that the blood groups and absence of sickling in the Bushmen support the hypothesis of Lehmann and Cutbush that the high frequency of cDe in Africa is an ancient characteristic, but that sickling is a comparatively recent introduction from western Asia. Our findings in the Hottentots give some support to this view, but their relatively high frequencies of CDe and cDE as well as of B suggest mixing with Negro stocks now living far to the north. If we accept the hypothesis of the recent introduction of sickling into Africa, we may perhaps imagine that the Hottentots represent a primitive Bushman-like stock originally living near the Equator, receiving a Negro component and then migrating south, all before the introduction of sickling. It must, however, be stressed that the original stock, though specialized in some ways, must have carried all the main features which now characterize African populations as a whole.

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DERMATOGLYPHICS OF BUSHMEN (SOUTH AFRICA)

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During his 1950–51 expedition in South Africa, with support of the Wenner-Gren Foundation, Martin Gusinde conducted studies on several populations. Among Professor Gusinde's records are finger prints and palm prints of Bushmen, which he generously has given to me for analysis and report.

These records are a significant addition to the gradually increasing materials for racial comparisons of dermatoglyphics. Bushmen had been known hitherto in this respect only through one series (Weninger, '36) that is far too small (32 subjects, and that reduced by incompletenesses of prints) to yield stable values. The new collections are larger and, for the Kun, large enough to yield results of reasonable stability even for comparisons of the sexes. (The form "Kun" is used here for simplicity, in preference to the phonetic spelling, "!kun," in which the "!" replaces the cerebral click; Gusinde, personal communication.)

This note purposes only: to place on record observations that will admit detailed comparisons with other populations, using data supplied in the listed references (too extensive for repetition here); to compare the groups of Bushmen among themselves, with emphasis on Kun and Barakwéngo because these two groups are represented by larger numbers. Only general comments are offered on comparisons with other populations.

MATERIALS AND METHODS

Brief accounts of the expedition, giving localities and general observations on the Bushmen, are available (Gusinde, '52, '53), and Gusinde has a detailed report in preparation.

The prints were made in the customary way; each sheet was marked with the locality, the group name, the name of the subject, sex, age and family relationship, if any, to others in the series.

The numbers of subjects available for the several determinations varied:

	MALE	FEMALE
Kun	164–195	181–217
Barakwéngo	44–61	61–83
Kánikwe	23	34–40
Háikom (also spelled Heikom)	17–18	20–21

The tables show the number on which each determination was based. Variation in numbers is due entirely to exclusions because of imcompleteness or technical faults of the prints. For example, a subject might be represented by clearly decipherable palmar impressions, on which full data were obtainable, but with lapses in the set of finger impressions necessitating omission of that individual in the finger-print data.

The prints were analyzed by the methods described by Cummins and Midlo ('43). The data here published are those considered most critical. A large body of additional data, that might be useful in further analyses, is available.[1] The supplementary tables, which include separate entries for males and females of each of the 4 groups and for right and left sides, list the following frequencies: finger-print types for individual digits (with whorls divided into three classes: typical concentric whorls, whorls with double-loop centers, lateral pockets and twin loops); the various configurational types (breakdown of the descriptive varieties of patterns and vestiges) for each of the 5 palmar areas; the positions of termination of each of the 4 palmar main lines; the types of axial triradi.

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[1] This material, in the form of mimeographed tables, will be supplied on request to the author.

Readers who are not acquainted with the standard comparative procedures in dermatoglyphics should understand that comparisons are drawn on the basis of group differences in the frequencies of characteristics that are common to all peoples. Thus, for example, the finger-print patterns of the Kun series present a notably low frequency of whorls, 16.1%; Australian aborigines in Arnhem Land (Cummins and Setzler, '51) stand at the opposite extreme, with whorls amounting to 75.3% of all patterns. The many other populations that have been studied (see references) present frequencies at various levels that are largely confined within this range.

OBSERVATIONS

Finger prints (table 1). The outstanding distinction among the 4 groups is in the low frequency of whorls (16.1%) and abundant arches (16.2%) in Kun; these incidences, which are essentially equal to the values reported by Weninger (15.1% and 16.4% respectively), are at the bottom range

TABLE 1

Percentile frequencies of finger-print types and indexes based on these frequencies

		KUN		BARAKWÉNGO		KÁNIKWE		HÁIKOM	
		M (164)	F (181)	M (44)	F (61)	M (23)	F (34)	M (17)	F (20)
FREQUENCIES	Whorls	15.1	17.1	30.7	25.9	38.7	32.1	30.6	24.5
	Ulnar loops	68.1	60.7	61.4	63.8	51.3	58.5	63.5	61.0
	Radial loops	3.8	2.9	2.7	0.8	3.0	3.2	3.5	4.0
	Arches	13.0	19.4	5.2	9.6	7.0	6.2	2.4	10.5
INDEXES	Pattern intensity [1]	10.21	9.78	12.55	11.64	13.17	12.59	12.82	11.40
	Furuhata [2]	21.0	26.9	47.9	40.1	71.3	52.0	45.7	37.7
	Dankmeijer [3]	86.1	113.5	16.9	37.1	18.1	19.3	7.8	42.9

[1] ([Whorls × 2] + Loops) ÷ 10.

[2] (Whorls ÷ Loops) 100.

[3] (Arches ÷ Whorls) 100.

of known populations. Considering the numbers of subjects the variations among Barakwéngo, Kánikwe and Háikom are not significant, though Barakwéngo and Háikom appea to be closer to each other than is either to Kánikwe. The Kun series is in sharp contrast to all three groups, which lie in a range common to a number of populations, some of them quite unrelated racially.

The well-nigh universal sexual contrast of more abundan whorls in males is present in Barakwéngo but reversed in Kun, notwithstanding that the usual lower frequency o arches holds in the latter. In spite of the reversal in Kun, th arch/whorl index is larger in females of this group, as i is consistently in the others and in populations generally.

The characteristic bimanual distinction of more abundan whorls and fewer arches in right hands is evidenced in both sexes of Kun and Barakwéngo, except that Barakwéngo males have reversed arch frequencies: right, 6%, left 4.5%. This ex ception is insignificant in view of the smallness of the sampl (44).

Dactylodiagrams of Kun and Barakwéngo constructed by the method of Poll (seen Cummins and Midlo, '43) demonstrate a trend in both sexes toward the ''rule of all pairs,'' and Kun females definitely conform to that rule.

Palmar configurational types (tables 2–6). The palm has 5 areas which are separately considered. In each of these areas the configuration may be a well-defined pattern (e.g. a loop), a vestige (suggesting an abortive pattern formation) or patternless (i.e., a monotonous system of parallel ridges lacking the recurvatures or other features that distinguish patterns and vestiges). Comparisons are drawn on the basis of frequencies of patterns plus vestiges, as contrasted with the patternless configurations whose frequencies are indicated in the implied percentile remainders.

Data for the *hypothenar* area (table 2) must be viewed with a reservation. An occasional hypothenar configuration of the L^r type, the prevailing form in all these groups, has the head of the loop situated so far dorsally on the ulnar

TABLE 2

Percentile frequencies of vestiges and true patterns in the palmar hypothenar area

	KUN				BARAKWÉNGO				KÁNIKWE				HÁIKOM			
	M (195)		F (216)		M (61)		F (82)		M (23)		F (40)		M (18)		F (21)	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
Vestiges	3.1	1.5	1.4	4.2	3.3		2.4	3.7	8.7	4.3		5.0			4.8	9.5
Patterns	29.2	25.1	28.7	22.7	23.0	21.3	24.4	15.9	34.8	26.1	27.5	20.0	38.9	16.7	33.3	23.8
Vestiges + Patterns	32.3	26.7	30.1	26.9	26.2	21.3	26.8	19.5	43.5	30.4	27.5	25.0	38.9	16.7	38.1	33.3
Vestiges + Patterns	29.5		28.5		23.8		23.2		36.9		26.3		27.8		35.7	
Vestiges + Patterns	29.0				23.5				31.6				31.8			

TABLE 3

Percentile frequencies of vestiges and true patterns in the palmar thenar/first interdigital area

	KUN				BARAKWÉNGO				KÁNIKWE				HÁIKOM			
	M (195)		F (216)		M (61)		F (82)		M (23)		F (40)		M (18)		F (21)	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
Vestiges	6.2	13.3	12.5	15.3	4.9	14.8	3.7	3.7	4.3	13.0	12.5	12.5		22.2		9.5
Patterns	15.4	37.4	14.4	34.3	1.6	11.5	2.4	8.5	13.0	26.1	12.5	25.0	5.6	16.7	4.8	4.8
Vestiges + Patterns	21.5	50.8	26.9	49.5	6.6	26.2	6.1	12.2	17.4	39.1	25.0	37.5	5.6	38.9	4.8	14.3
Vestiges + Patterns	36.2		38.2		16.4		9.1		28.3		31.3		22.2		9.5	
Vestiges + Patterns	37.2				12.8				29.8				15.9			

margin that a print of the flat of the palm appears patternless in the hypothenar area. These palm prints were not rolled to include the ulnar margin, hence it is possible that a few such L^r patterns were missed and erroneously classified as patternless configurations. However, both sexes of all 4 groups present the typical dextral excess of patterns and vestiges. The total frequencies are not noteworthy and the slight differences among the groups must be discounted in view of the sizes of the samples and the nature of the prints as just described.

The *thenar/first interdigital* area (table 3) presents a striking distinction between Kun and Barakwéngo, with 37.2% and 12.8% as the respective frequencies of patterns plus vestiges. The Kun frequency stands among the highest known. Just as in the case of finger prints, Barakwéngo and Háikom appear to be more closely related to each other than is either to Kánikwe. Both sexes of all 4 groups display the characteristic excess of patterns plus vestiges in left hands.

The *second interdigital* area (table 4) presents a noteworthy high frequency of patterns plus vestiges in all 4 groups, but their incidence of 33.4% in Kun is considerably greater than the 21.2% in Barakwéngo. The recognized dextral excess is marked in both sexes of all the groups.

The *third interdigital* (table 5) presents rather high frequencies, but such are common among varied populations. Patterns plus vestiges are more frequent in Kun (53.3%) than in Barakwéngo (45.8%) or the other two groups. As before, Kánikwe is less close to Barakwéngo and Háikom than these two are to each other. The characteristic dextral excess of patterns plus vestiges prevails in all 8 samples except Kánikwe females.

The *fourth interdigital* area (table 6) also is featured by high frequencies of patterns plus vestiges, but again this occurs in varied populations. The Kun frequency (84.4%) is higher than Barakwéngo (71.8%). Kánikwe and Háikom are here closer to each other (and to Kun) than is either to Barakwéngo. The characteristic excess in left hands pre-

TABLE 4

Percentile frequencies of vestiges and true patterns in the palmar second interdigital area

	KUN				BARAKWÉNGO				KÁNIKWE				HÁIKOM			
	M (195)		F (216)		M (61)		F (82)		M (23)		F (40)		M (18)		F (21)	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
Vestiges	27.7	11.8	20.4	9.7	23.0	8.2	19.5	3.7	17.4	8.7	15.0	7.5	27.8	5.6	19.0	4.8
Patterns	20.5	15.9	17.1	10.6	13.1	4.9	9.8	2.4	17.4	8.7	10.0	2.5	11.1			
Vestiges + Patterns	48.2	27.7	37.5	20.4	36.1	13.1	29.3	6.1	34.8	17.4	25.0	10.0	38.9	5.6	19.0	4.8
Vestiges + Patterns	37.9		28.9		24.6		17.7		26.0		17.5		22.2		11.9	
Vestiges + Patterns	33.4				21.2				21.8				17.1			

TABLE 5

Percentile frequencies of vestiges and true patterns in the palmar third interdigital area

	KUN				BARAKWÉNGO				KÁNIKWE				HÁIKOM			
	M (195)		F (216)		M (61)		F (82)		M (23)		F (40)		M (18)		F (21)	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
Vestiges	2.6	4.6	3.2	7.9	4.9	13.1	8.5	14.6		21.7		7.5		11.1		9.5
Patterns	63.6	33.8	63.0	34.3	55.7	31.1	36.6	18.3	43.5	13.0	32.5	30.0	66.7	38.9	42.9	23.8
Vestiges + Patterns	66.2	38.5	66.2	42.1	60.7	44.3	45.1	32.9	43.5	34.8	32.5	37.5	66.7	50.0	42.9	33.3
Vestiges + Patterns	52.3		54.2		52.5		39.0		39.1		35.0		58.3		38.1	
Vestiges + Patterns	53.3				45.8				37.1				48.2			

TABLE 6

Percentile frequencies of vestiges and true patterns in the palmar fourth interdigital area

	KUN				BARAKWÉNGO				KÁNIKWE				HÁIKOM			
	M (195)		F (216)		M (61)		F (82)		M (23)		F (40)		M (18)		F (21)	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
Vestiges	9.2	10.3	7.9	8.8	4.9	11.5	11.0	11.0	8.7		5.0	5.0	16.7	11.1	4.8	4.8
Patterns	67.7	80.0	70.8	82.9	50.8	63.9	61.0	73.2	78.3	87.0	85.0	87.5	61.1	83.3	71.4	90.5
Vestiges + Patterns	76.9	90.3	78.7	91.7	55.7	75.4	72.0	84.1	87.0	87.0	90.0	92.5	77.7	94.4	76.2	95.2
Vestiges + Patterns	83.6		85.2		65.6		78.0		87.0		91.3		86.1		85.7	
Vestiges + Patterns	84.4				71.8				89.2				85.9			

TABLE 7

The palmar main-line index: means and right/left ratios

	KUN				BARAKWÉNGO				KÁNIKWE				HÁIKOM			
	M (193)		F (217)		M (60)		F (83)		M (23)		F (40)		M (18)		F (21)	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
Mean index	9.39	7.34	8.99	7.50	9.17	7.35	8.99	7.11	8.04	6.69	7.70	6.77	9.22	7.44	7.71	6.04
	8.37		8.24		8.26		8.05		7.37		7.24		8.33		6.88	
R/L ratio	128		120		125		126		120		114		124		128	

vails throughout except in Kánikwe males, where the bimanual frequencies are equal.

Palmar main lines (table 7) are useful as an indicator of the slant of ridges in the distal region of the palm. Group comparisons are most conveniently made with the use of the integral value known as the main-line index; its progressively higher values indicate an increasing degree of transversality. Combining the sexes, and right and left hands, the seriation of the indexes is Kun, 8.31; Barakwéngo, 8.16; Háikom, 7.61; Kánikwe, 7.31. Kun, therefore, possesses the highest degree of transversality. The generally recognized bimanual distinction of greater transversality in right hands appears, as would be expected, in both sexes of all 4 groups. Reduced to right-left ratios, an interesting sexual distinction between Kun and Barakwéngo appears. Ordinarily, the bimanual inequality is less in females, in a degree equal to or approaching that shown in Kun (male, 128; female, 120); in Barakwéngo, however, the difference is leveled or even possibly reversed (male, 125; female, 126). The possibility here suggested is perhaps strengthened by the finding in Háikom (male, 124; female, 128), a group that has been shown to resemble Barakwéngo more closely than Kánikwe in some other respects.

TABLE 8

Percentile frequencies of reduction (X, x) and absence (0) of palmar main line C

	KUN				BARAKWÉNGO				KÁNIKWE				HÁIKOM			
	M (193)		F (217)		M (60)		F (83)		M (23)		F (40)		M (18)		F (21)	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
X	1.0	5.2		5.1	1.7	6.7	3.6	6.0		4.3	2.5	5.0		5.6		
x	0.5	2.1	0.5	0.5	1.7	1.7	2.4	1.2								
0	4.1	9.8	2.8	6.9	6.7	6.7	7.2	14.5	4.3	4.3	7.5	7.5				
TOTALS	5.7	17.1	3.2	12.4	10.0	15.0	13.3	21.7	4.3	8.7	10.0	12.5		5.6		
	11.4		7.8		12.5		17.5		6.5		11.3		2.8			
	9.6				15.0				8.9				1.4			

Reduced states plus absence of *Line C* (table 8) are less common in Kun (9.6%) than in Barakwéngo (15.0%). The usual greater incidence in left hands holds in all the groups and in both sexes of each.

SUMMARY

Finger prints and palmar dermatoglyphics are analyzed in 4 groups of Bushmen, with comparative emphasis on the two represented by larger numbers of subjects: Kun, with observations on 164–195 males and 181–217 females (unlike numbers being available for the various determinations); Barakwéngo, 44–61 males and 61–83 females.

Kun is distinguished from Barakwéngo in a number of respects, principally among them: finger prints have fewer whorls (16.1% *vs.* 28.3%) and more abundant arches (16.2% *vs.* 7.4%); all the configurational areas of the palm present more frequent patterns plus vestiges — hypothenar 29.0% *vs.* 23.5%, thenar/first interdigital 37.2% *vs.* 12.8%, second interdigital 33.4% *vs.* 21.2%, third interdigital 53.3% *vs.* 45.8%, fourth interdigital 84.4% *vs.* 71.8%; ridge courses over the distal portion of the palm, as reflected in main-line indexes of 8.31 *vs.* 8.11; palmar main line C is less frequently suppressed, 9.6% *vs.* 15.0%.

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THE PHYSIQUE OF BUS AND TRUCK DRIVERS: WITH A REVIEW OF OCCUPATIONAL ANTHROPOLOGY [1]

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Knowledge of the physique of occupational groups can be valuable in such diverse fields as anthropology, medicine, engineering, psychology, and vocational placement. The vigorous development of these areas in recent years makes all the more puzzling the dearth of American studies of the worker's physique. Anthropologically, such data on a large scale permit description of the physical makeup of a nation, for most men work for most of their lives. It is a truism that the average man — not a student, not a soldier, not a hospital patient, but the normal healthy working man — is largely unknown, an ignorance which severely handicaps the human biologist. Data from many occupational groups can be combined to give a national picture. Moreover, only by such research can we decide whether and to what extent occupation, like age, sex, and race, need be controlled in studies of physique; and what may be the effect of occupation, as one aspect of man's environment, on his physique.

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[1] This study is one of a series being carried out at the Harvard School of Public Health in the field of human body size, vehicular design, and accidents. It is sponsored by the Commission on Accidental Trauma of the Armed Forces Epidemiological Board and supported by funds from the Research and Development Division, Office of the Surgeon General, Department of the Army.

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Medically, it is often necessary to establish physical standards for specific jobs, to prevent misfits, accidents, or other health hazards (Hanman, '45). Anthropometric data on successful and superior workers may be useful here. Another aspect of industrial medicine is the apparent predilection of some diseases for certain occupations. Even in such obvious cases as exposure to noxious agents — physical, chemical, or bacteriological—, some persons are more resistant than others, and their selection may allegedly be aided by the anthropologist (Jagic and Seyfried, '40; Hanhart, '53). But more subtle are associations like the greater incidence of coronary artery disease in Britain (a) among "general practitioners" than other physicians and (b) among workers in physically less active jobs (bus drivers, clerks, telophonists) than in the more active, such as bus conductors and postmen (Morris *et al.,* '53). Actually, bus driving is fairly strenuous. Other possible associations between occupation and disease are the alleged high incidence of duodenal ulcer among executives and foremen, and of gastric ulcer and perforations from both types of ulcer among manual workers (Ivy *et al.,* '50; Doll and Jones, '51). Does the job "cause" the disease, or do persons who choose certain jobs have psycho-physical constitutions associated with certain types of pathology? Doll and Jones ('51) and Wretmark ('52) prefer the latter explanation for ulcer, while the role of constitution is stressed in two discussions (Anon., '54; Benton and Rusk, '54) of the differential occupational incidence of coronary artery disease. Both recommend the study of physique in occupational groups as an initial step toward distinguishing innate from environmental factors in disease. Here is a promising and largely untapped field of study.

The psychologist, sociologist, and the executive, no less than the physician, are concerned with occupational choice and achievement. Who, in a free society, chooses what job, and why? Once having chosen, who succeeds? How large a part is played by genetic or constitutional factors of physique and temperament; are the latter associated, and how closely? Anthropological data may help answer such questions and thus contribute to the new fields of vocational guidance and selection — fields which Mellanby ('43), when Secretary of the Medical Research Council of Great Britain, judged even more important for industrial medicine than toxicology and the prevention of occupational hazards.

At a more mundane level, anthropological data on occupational groups have an immediate, practical value for "human engineering," or the design of equipment for human use. It would appear self-evident that machines and clothing should be designed for the population to be served; but in both military and civil experience, such has not always been the case, sometimes with serious or fatal results (McFarland *et al.*, '53). Space for the operator; design and placement of controls and strength needed to operate them; size and shape of clothing and personal equipment; the effect of ageing on human strength and dimensions; all can be properly assessed only by anthropometric data.

For all these reasons, the present study is submitted as a description of physique in a sample of heavy vehicle drivers. This job category, containing some 5–6 million men, is perhaps the largest distinct occupational group in the country (McFarland *et al.*, '54). (Agriculture, which employs more workers, includes many very diverse occupations.) Classical anthropometry, including grip strength and endurance tests, as well as somatotyping, have been employed; and champion as well as average drivers are included.

REVIEW OF LITERATURE

Occupational anthropology has received scant attention in the United States, unlike the related fields of physical fitness, psychophysiological correlates of physique, the physique of athletes, and "human engineering." For example, this *Journal* and *Human Biology* have published, since their inception, but one article each primarily on the subject (Reed and Love, '32; Garn and Gertler, '50). American journals of medicine, industrial medicine, physiology, and applied physiology have had to our knowledge only the few studies of aviators mentioned below. A brief survey of the field may therefore be in order.

Occupational anthropology in general. Systematic study of the worker's physique began with Quetelet (1835). This Belgian statistician, who devised the term "anthropometry" and founded the science, reported on 1505 working-class children. At each age from 9 to 18, boys and girls working in factories weighed less than those who did not, the differences becoming marked only after puberty. Quetelet also found masons and carpenters to have stronger grips than domestic servants.

During the 19th and early 20th centuries, most research came from military surgeons. Recruiting statistics provided data on large numbers of young men, despite the drawbacks of few and unstandardized measurements, youth and physical immaturity of subjects, doubt as to their ultimate occupation, and usual failure to include statistics on rejected men. Typical of these studies was Livi's (1897; '11) demonstration, based on 300,000 Italian recruits, that manual laborers and farmers were more robust than students. He used Pignet's index, or height minus (chest circumference plus weight). Teamsters had the best physiques, barbers and tailors the worst — i.e., smallest stature and chest girth. Civilian occupation was noted in the monumental American studies of Army anthropology in Civil and both World Wars (Gould, 1869; Baxter, 1875; Davenport and Love, '21; U.S. Selective Service, '41; Hooton, '48; Randall, '49a), but was analyzed only by Davenport and Love in relation to disease and by Hooton in relation to body type. Among 38,000 American troops, Hooton found that military jobs requiring more physical exertion (combat gunner, transportation, maintenance) were held by better muscled soldiers, while the least muscular and fattest abounded in supply and administration. In civilian life, students were long and thin, professional and semi-professional workers poorly muscled, as were salesmen and clerks.

All these findings held true for both Whites and Negroes but were less marked for the latter.

From military statistics came a potent stimulus to occupational anthropology, namely, concern with the quality of national physique. This, together with an increasing interest in the worker's health, led to a series of British investigations. Farmer ('22) found anthropometrically determined physical type to "play a part — though a small one — in proficiency in work" among 130 girls performing three different tasks in a candy factory. Cathcart *et al.* ('35) quoted Beddoe's and Roberts' conclusions 65 and 52 years earlier that stature in young Britons increased in order from sedentary workers, like tailors, to urban and indoor artisans, clerks and commercial workers, and professional men. The older authors had not eliminated the effects of geography and social class. In his own study, based on 13,656 men aged 14 years and above in several industries, Cathcart showed that within a given age and geographical area, transport workers were taller, heavier, and stronger than clerks; and that in these respects students surpassed employed men, who in turn surpassed the unemployed. However, only height, weight, and grip strength were observed. Many sub-adults were included, and comparison was by industry rather than occupation, with "transport workers" comprising loaders, helpers, checkers, clerks, and conductors as well as drivers. Kemsley ('50) reported, among 22,500 British men and 33,500 women, that miners were heavier but shorter than workers in heavy industry, who were in turn taller and heavier than those in clerical, mercantile, and light industrial trades. However, as Kemsley admitted, little confidence can be placed in such data on fully clothed and shod subjects.

To compare health conditions in 10 American industries, Britten and Thompson ('26) of the U.S. Public Health Service gathered medical data — including height, weight, chest girth, and grip strength — on 10,000 American workingmen. However, ethnic selection was so strong in their industrial groups — all their garment workers being Jews, their cigarmakers Spanish-Cuban, and 83% of their pottery glazers Old American and English, for example — that anthropometric comparison could only be by ancestry rather than occupation. The need for physical standards for American women led Bayer and Gray ('34, '36) to measure 100 women of diverse occupations, chiefly housewives. Of O'Brien and Shelton's ('41) 10,042 women in 4 occupational groupings, students were tallest; housewives and WPA-employed women, shortest and heaviest, with greatest girths; while other working women weighed the least and had the least girths.

Another source of data for occupational anthropology has been applied physiology, incidental to research on such problems as ageing and functional efficiency. Ufland ('33) showed that among 4060 Leningrad workers, bakers at every decade from the third to sixth had stronger hand grips than housepainters, who in turn surpassed printers. From an elaborate study of growth in 668 German apprentices, boys and girls between the ages of 14 and 19, Lehman and Szakall ('41) reported that smiths were stockier and stronger than tradesmen and students, while barbers and tailors had the poorest physiques of all. They concluded, without adequate evidence, that basic physique is genetically determined; the physical homogeneity of various occupations is the result of conscious and unconscious selection; and occupation has a relatively slight influence on physique.

An excellent psychophysiological study of 133 French arc-welders by Laugier *et al.* ('37) included a few metrical traits. In weight, the good, average, and poor welders did not differ. In height, elbow height above ground, hand length, and grip strength, the good and average welders did not differ, nor welders as a group from engineers; while poor welders were slightly but insignificantly inferior to the combined good and average. Marked correlations with ability were found, however, in vital capacity, vision, and several psychomotor tests. In a later paper, Laugier and Weinberg ('39) remarked that among railroad switchmen, individuals of stocky build seemed numerous, but gave no data. Fortier ('46) found no difference in the weight/body surface and shoulder girth/hip girth indices between 109 lumberjacks and 349 mixed workers in the Quebec lumber industry, the latter including cooks, drivers, engineers, handymen, and the like. Karvonen's ('52) anthropometric data on 32 finalists in the 1951 Finnish wood-cutting competition showed these champions to be taller than the average Finn, chiefly due to greater trunk length; they also had longer arms, broader shoulders, and deeper and wider chests. Unfortunately, no figures were given for the average lumberjack. (See also Eränkö and Karvonen, '55.)

Contributions to occupational anthropology from racial theorists have been dubious. Brezina and Wastl's ('29) much-quoted observation (e.g., Schwidetzky, '51, p. 145) that Viennese streetcar motormen were more Easteuropid and less Nordic than pavement workers, rest on but 50 motormen and 20 pavement workers. Apart from possible uncontrolled selective factors, the motormen were actually somewhat taller! However, neither height nor cephalic index differed significantly in the two groups, as should occur with real racial differences. Gamble ('44) speculated that "a large number of Dinarics are exceptionally good technicians," but found only two Dinarics among 103 Northern Irishmen examined.

Students of criminal anthropology have pursued Lombroso's occupational interests, but with few positive findings. Goring ('19, p. 115) stressed the genetic and somatic basis of occupation, without evidence. In Skerlj's ('33) study of German and Yugoslav prostitutes, the small series and inadequate controls (schoolgirls and gymnasts not really comparable in age, ancestry, or social status) may obscure whatever differences, if any, exist. His data hardly support his conclusions that lower-class prostitutes are fatter than those of higher class, or than non-prostitutes. Among broad occupational groupings (not specific jobs) in 4102 American criminals, Hooton ('39) found some significant metrical differences, but none in body build.

A major impetus to occupational anthropometry has come from students of constitution. Extensive German research among normal persons, largely following Kretschmer, was summarized by Coerper ('29), who himself classified occupations by constitutional type. Thus, locksmiths, transport workers, and shoemakers were "muscular," lithographers "cerebral," cabinet-makers and weavers "respiratory." Coerper presented no objective evidence for these designations, nor for the asserted correspondence between school children's occupational choice and their physique. Neither did Zeller ('34) in a later review. Among 2500 Russian boys and girls, aged 14 to 18, Stefko ('29) found no difference in body build ("muscular," "thoracic," "abdominal," "asthenoid") between professional-and-technical and factory-and-trade students, except for the latter's excess of "infantile" physiques — 21% vs. 8%. He concluded (without proof) that nutrition rather than occupational factors accounted for the greater height, weight, and chest girth in the former group. Wilson's ('38) attempt to correlate Kretschmerian type with success in military flying was inconclusive, though he did refute Kretschmer's ('36, p. 26) "unfounded statement" that asthenics are better built for flying.

Tschelzowa ('31) compared body build among 465 pneumatic hammer drillers, 431 bakers, 98 butchers, and an unspecified number of brewers and sailmakers, all patients at the Leningrad Institute for the Study of Occupational Diseases. By the Sigaud and Kretschmer typologies, pure "muscular" physiques predominated in all 5 occupational groups — 50% of butchers and 32% of sailmakers marked the extremes. "Respiratory" physiques were most frequent among the sailmakers, with 30%; "digestive" types were commonest (16%) among brewers, rarest (3%) among sailmakers. About 20% of all 5 series were of mixed or uncertain body build. Tschelzowa's types can hardly correspond to Kretschmer's, whose pure types include only 10% of normal persons; however, there is little doubt that sailmakers differed from the other 4 groups, all of whom performed more physical labor.

The "biotypology" of Pende ('28, '32), though it has inspired many Italian and South American authors (e.g., Baisi, '30; Perrusi, '32; Agnullo, '33; Ferraz, '45; Boccia, '50; de Vasconcellos, '51), seems to rest more on impression and assertion than on actual data. The hypothetical elimination from certain jobs of "constitutional inferiors" is in fact possible by more conventional medical and psychiatric techniques (Rheingold, '44). We have found no evidence for the alleged importance of "biotypology" for occupational or military selection.

In a field where speculation has far outrun fact, the solid work of Brezina and collaborators ('27, '29) stands out. A detailed comparison of 100 Viennese smiths and 90 printers over the age of 20 disclosed some significant metrical differences, but even more clearcut results by constitutional ratings. The latter were assigned both inspectionally and metrically, a welcome innovation; the two methods corresponded fairly well. The smiths were the more "athletic," "respiratory," and "masculine," less "digestive" and "asthenic." The smiths showed fewer age changes (increased weight and abdominal girth, decreased shoulder breadth) than the printers. Weak points in this otherwise admirable study are that the printers were all from one firm, introducing the possibility of selection, and that trousers and shoes were retained during measurement. If clothing differed between the two groups, subtraction constants might be misleading.

Brezina also found, among 2815 Viennese apprentices aged 14 to 17, that at each age masons and mechanics exceeded barbers and tailors in height, weight, chest circumference, and stockiness. Rosenfeld ('31) extended this work to 4130 more boys and 1474 girls. Male apprentice metal-workers showed minimal differences from non-metal-workers, with suggestions that the latter might mature more slowly. Locksmiths were taller, heavier, and had larger chests than mechanics, electricians, and machine builders. Among the girls, seamstresses showed no differences from other apprentices.

In the study of Viennese transport workers already mentioned, Brezina and Wastl ('29) compared streetcar motormen, conductors, repairmen, pavement workers, and minor officials; a total of 192 men, about half aged 25 to 30 and the rest 45 to 50. Significant metrical differences emerged: pavement workers, both young and old, who performed the most physical labor, had the least weight and hip and thigh girths. They also showed the slightest age increase in these dimensions, while conductors ''aged'' more (in this sense) than motormen, who performed about the same physical work. Body build analysis gave even sharper differences: motormen were the most ''athletic,'' conductors the least, while pavement workers alone lacked ''pyknics.''

Of many efforts to improve Kretchmer's typology by recognizing continuous variation in human physique, one which has been applied to occupation with positive claims is Sheldon's ('40) somatotyping. Seltzer ('45, '46 and in Hooton, '45) found that of 27 Harvard Grant Study (i.e., physically and academically superior) students weak in morphological ''masculinity,'' 6% (sic) intended to enter business, contrasted with 22% of prospective businessmen among 150 Grant Study subjects. Also, the less masculine students concentrated in the humanities rather than the natural or social sciences. He observed weak masculinity in 8.5% of 59 chainstore managers, 10% of 257 Grant Study subjects, 15% of 1800 Army draftees, 20% of communication officers, and 26% of 78 chaplains. Seltzer also noted characteristic ''disproportions'' (extreme values of metrical indices) related to psychiatric status and cognitive and presumably occupational motivation. The chainstore managers, especially 31 of the more successful, had fewer ''disproportions'' than Grant Study subjects. Hooton's ('48) research on soldiers, using a modified Sheldon technique, has already been mentioned. Garn and Gertler ('50) found 20 research workers significantly less endo-, less meso-, and more ectomorphic than 80 general factory workers in the same plant. Metrically, the research men were taller and thinner. Among Oxford students, Parnell ('54) has related somatotype to academic and athletic choice and performance.

Aviators. As a group, one of the newest occupations has been among the most intensively studied. Critical bibliographies are given by McFarland ('46, '53) and Damon ('55). McFarland *et al.* ('39) and McCormick ('47) showed that civilian pilots were taller, heavier, and stockier than the general population, and predominantly mesomorphic. Among wartime Army flyers, Damon found that the more sucessful were the more mesomorphic and masculine, with larger chest girths, both absolutely and relative to stature and head circumference. Successful combat fighter pilots differed metrically and temperamentally from bomber pilots, while both groups showed fewer of Seltzer's "disproportions" than air cadets. Bombardiers and navigators were significantly more variable in physique than pilots, co-pilots, or cadets.

In an attempt to quantify the athletic-asthenic continuum, Schlegel ('50, '50a) has simplified constitutional anthropometry to a single dimension, left hand circumference, which he has related to disease, sport, and occupation. Among 140 Luftwaffe flyers, 10 were asthenic (< 19 cm), of whom 8 did poorly, whereas 20 of the 27 athletics (> 21 cm) were above-average flyers. The importance of hand circumference for sport and occupation is inferred from these findings, without further data.

Teamsters and truck drivers. Teamsters or other heavy vehicle drivers have been recognized as a distinct occupational group for centuries. Ramazzini (1713), the father of industrial medicine, noted their occupational hazards (hernia, vascular rupture, gluteal infections), but not their physique. Both Livi (1898) and Cathcart ('35), as mentioned, found them relatively tall, with large chests, both absolutely and relative to height; while Coerper ('29) and Hooton ('48) regarded them as "muscular." However, transport workers were physically indistinguishable from the rest of Hooton's ('39) criminal series. Unfortunately, extensive psychophysiological studies on 889 American professional truck drivers (Jones *et al.*, '41) and 150 in France (Goguelin, '50) included few or no usable physical measurements.

Japanese research. Before concluding this review, we should mention the extensive data on occupational anthropology hidden to Western eyes in the Japanese literature. From 1932 to 1941 alone, dozens of English or German references in the Japanese Journal of Medical Sciences, Anatomical Abstracts, summarize all too briefly the anthropometry of such varied groups as coolies, divers, factory girls, farmers, miners, prostitutes, and sailors.

Conclusions from review of literature. We agree with Simonson ('47) that the physiological and psychological correlates of constitution have not been studied exhaustively, but that this is desirable in industrial research. Some tentative conclusions seem justified by the evidence. (1) Workers in certain occupations differ consistently in physique from other workers (e.g., smiths and butchers vs. barbers and tailors), the differences often but not always corresponding to the exertion required. This lack of complete correspondence, plus differences (a) among apprentices of various trades, (b) among workers expending the same amount of energy (streetcar conductors and motormen), and (c) between good and average workers within one occupation (airmen), all indicate that selection as well as adaptation, and psychological as well as purely physical factors, are at work. (2) Physiological processes like maturation and ageing may differ even more, from one occupational group to another, than physique at any given age — again, with no necessary relation to the job. (3) Generalized descriptions of body build differentiate occupational groups more clearly than do separate dimensions, but anthropometry is still necessary to objectify constitutional appraisal and to isolate the elements responsible for the differences observed.

Based on the above survey, desiderata for research in occupational anthropology are easy to state, though difficult to achieve. No study to date, including the present, satisfies them all. Controls for any group studied should exist, either as national standards or as comparable data on other occupational groups. The occupations studied should be specific, the subjects adult and engaged in the work for some years, the physical measurements numerous and relevant — i.e., anthropometry plus more comprehensive body build descriptions. The data should be obtained under standardized conditions by as few observers as possible — ideally, one observer for all groups compared. Samples should be large, with age, race, geographical origin, and cultural selective factors eliminated or controlled. Good, average, and poor workers within a given trade should be compared, as a practical test of the body-behavior hypothesis.

SUBJECTS AND METHODS

As part of research on highway transport safety conducted by the Harvard School of Public Health, anthropometric data were obtained on 272 regular bus and truck drivers and 103 champion truck drivers, all healthy and working regularly.[4] The bus drivers represented 4 companies in Massachusetts, New Hampshire, Rhode Island, and New York; the truckmen, 4 companies in Massachusetts, Vermont, New York, and Texas. Only long-haul, not city, drivers were included. The 103 champion truck drivers, from every state, were competing at annual nationwide "Roadeos" in 1950 and 1951. Most drove long-haul routes, but 27 were city pick-up and delivery drivers, who load and unload cargo themselves. Accident-free for at least a year, the champions had won gruelling state contests comprising written and practical tests of first aid, automotive maintenance, rules of the road, and driving skill under intense pressure. They were indeed a select group — unquestionably among the country's finest drivers.

Regrettably, due to unwarranted fear of offending the men or their unions, inquiry into ancestry was made only after the study was well underway. The few Negroid regular truckmen have been discarded for present purposes; there were none among the busmen, Texas truckmen, or champions. Table 1 shows what is available; it permits the conclusion that the drivers were predominantly Northwest European in origin, with a major but indeterminate fraction Old American-British. Irish, Gallic and Mediterranean strains were well represented. The only real difference between the combined regular and the champion series was perhaps the Germanic deficit among the former, doubtless due to their lack of Midwesterners. The Old-American-British deficit among the "regulars" may reflect merely inadequate information; if real, it is certainly less than appears in Table 1.

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[4] This portion of the study was supported by the National Association of Automotive Mutual Insurance Companies, the American Trucking Associations, and the National Association of Motor Bus Operators.

TABLE 1

Ancestry of drivers

	NORTHEAST BUS [1]	NORTHEAST TRUCK [1]	TEXAS TRUCK [2]	CHAMPION TRUCK [2]	TOTAL
Old Am., Brit.	20	9	38	51	118
Irish	16	10	12 [3]	7 [3]	45
French, Fr. Can.	14	11	2	7	34
Germanic	1	1	5	18	25
Scand.	1	3	1	3	8
Slavic	1	0	2	4	7
Medit.	10	14	1	3	28
Near East	1	0	0	0	1
Jewish	1	4	0	0	5
Latin Am.	0	0	1	2	3
"Northwest Eur."	29 [4]	41 [4]	0	0	70
Unknown	7	9	2 [5]	7 [5]	25
Total	102	104	64	102	369 [6]

[1] Based on names, hence only approximate. Attribution only when reasonably certain.

[2] Based on actual inquiry. Nine Texans and two champions also claimed Indian admixture (less than half); two Texans were half Indian, and one was three-quarter Indian.

[3] Some "Irish" ancestry in these two groups is Northern or "Scotch-"Irish, hence perhaps should be listed as Old American-British.

[4] A large but unknown fraction are Old American-British.

[5] Subject and both parents born in U. S. — probably most of these are Old American-British.

[6] A few subjects were omitted for various reasons.

The measurements were chosen for utility in vehicle design, with somatotype added for its possible bearing on selection. Photographs could be taken only on the Texas truckers;

the rest were somatotyped by the height/$\sqrt[3]{\text{weight}}$ ratio plus anthroposcopic judgement, a technique yielding ratings close to those based on photography (Damon, '55). Such ratings without detailed weight histories would now be called "phenotypes" rather than "somatotypes" by Sheldon ('54, p. 19). Hand grip was taken by a Collins dynamometer; grip endurance, by repetitive squeezes to exhaustion on a grip-strengthening device initially calibrated at 28 lbs. However, this "Grip-o-Steel" became weaker with use and finally broke, making its data useless except for gauging laterality. The subjects were nude. All of the 103 bus and 104 regular truckmen, plus the 43 truck champions of 1950, were measured by one of us (A.D.) who also made all somatotype ratings except those on the 60 champions of 1951. These men were studied by Mr. W. A. Hall (who also measured and, with Mr. A. L. Moseley, photographed the Texas truckmen) and by Mr. George Maranjian. Somatotype ratings did not differ as between the two groups of champions. The three observers, trained in the Harvard anthropometric laboratory, had standardized their technique before beginning work, but the inevitable divergences occurred for some traits, which will therefore be presented for fewer subjects than the total.

The problem of control groups has not been solved, since comparable data do not exist for American workingmen of this age. Randall ('49) reported some of the same measurements for 1000 26-year-old soldiers, as did Garn and Gertler ('50) for 80 Massachusetts soap factory workers. However, the latter were taller than most Americans and had the astonishing mean weight of 178.9 lbs. (81.4 kg), probably the highest of any "unselected" series yet recorded (cf. Roberts, '53). They are thus a quite special group. The large U.S. Selective Service ('43) series is certainly representative, but includes only height, weight, and chest circumference on a population averaging 26 years of age. As for somatotype standards, Sheldon's ('54) 46,000 men, drawn largely from colleges, hospitals, and certain military groups, "cannot pretend to represent completely a national population" (ibid.,

TABLE 2

Drivers vs. "General Population"[1]

	U.S. SELECTIVE SERVICE ('43)		RANDALL ('49)	GARN AND GERTLER ('50)[2]		SHELDON ('54)		REGULAR (NON-CHAMPION) DRIVERS	
NUMBER	3,000,000 M	V	1000 M	80 M	V	46,000 M		269 M	V
Age (yrs.)	26		26	36	16.3			37	22.1
Weight (lbs.)	152	15.1	158	179	16.0			167	16.7
Stature (cm)	173.9	4.1	174.3	176.3	4.1	174.1		173.6	3.5
Span				180.2	4.6			179.7	3.8
Head Circ.			56.8					56.8	2.7
Biacromial				40.8	3.8			40.0	4.5
Chest Circ.	90.8	7.5	93.4					97.8	8.0
– Brd.				30.9	5.6			29.9	7.6
– Depth				23.3	12.6			22.7	10.4
Bi-iliac				30.5	6.6			30.0	6.0
Hand Lgt.			19.4	19.3	4.3			19.2	4.4
– Brd.			8.8	8.9	5.9			8.7	5.3
Foot Lgt.			26.6					26.7	12.8
Ht./$\sqrt[3]{\text{wt.}}$	12.80		12.69	12.28	8.6			12.48	5.1
					S.D.		S.D.		S.D.
Endomorphy				3.95	1.6	3.34	1.1	3.58	1.3
Mesomorphy				4.09	1.1	4.11	1.0	4.61	0.8
Ectomorphy				2.56	1.7	3.42	1.2	2.45	1.3
Gynandromorphy						2.17[3]		1.66	0.7

[1] See text for discussion — page 725 and footnote.

[2] Computed from Garn and Gertler's table 2.

[3] For 2500 Air Force cadets; 2.24 for 4,000 college men (Sheldon '49, p. 20).

p. 11). The number of subjects at each age and in various occupations was not specified, nor were somatotype distributions presented by age or occupation. We utilize all of the foregoing studies in table 2 with reservations, as affording the best available comparative data.[5]

In addition, some 2500 Army drivers were sorted from the 25,000 soldiers measured by the U.S. Quartermaster Corps at demobilization in 1946 (Randall, '49; Newman and White, '51). Access to the material was kindly granted by Dr. R. W. Newman. Heavy vehicle drivers were not distinguished from jeep and staff car drivers. These men had served at least one year, but 85 per cent had less than two years' service. In view of their youth (24.4 years) and brief, varied driving experience, they cannot be compared directly with the civilian drivers, averaging 36 years in age and about 10 years as professional drivers; but it seemed worthwhile to compare them to the total Army series.

RESULTS

All differences were significant at or below the one per cent level, unless otherwise stated.

Civilian drivers. Regular bus and truck drivers differed only in mesomorphy and dysplasia, the truckmen being more mesomorphic (4.91 vs. 4.60, at about the 94th and 92nd percentiles of Sheldon's ['54, p. 33] 46,000 men) and less dysplastic (3.35 vs. 3.91). The busmen were more variable in laterality of grip, the truckmen in abdominal depth. With these few differences among the 46 traits observed, the two groups could be readily combined.

The Texas truckers, however, were another matter, being taller and thinner than the combined Northeastern bus and truckmen, with narrower and shallower chests, narrower hips, longer forelimbs and feet, and smaller head, chest, and

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[5] Among 2194 Army inductees at Fort Dix, New Jersey, a physically superior segment of the "general population," Sheldon found average endomorphy 3.76, standard deviation 1.14; mesomorphy 4.42, s.d. 0.92; and ectomorphy 3.15, s.d. 1.09. Twenty-three per cent fell below 4 in mesomorphy. (Unpublished data, 1955. Quoted by permission.)

TABLE 3

Texas truckmen; and regular drivers vs. champion drivers

NUMBER	TEXAS TRUCKMEN I 65 [1] M	 s.e.	REGULAR BUS AND TRUCKMEN (INCL. TEXANS) II 269 [2] M	 s.e.	CHAMPION TRUCKMEN III 103 [3] M	 s.e.	DIFFE II v
Age (yrs.)	35	1.0	37	0.5	34	0.6	.0
Weight (lbs.)	161	3.2	167	1.7	167	2.7	
Stature (cm)	175.8	0.7	173.6	0.4	175.3	0.6	.0
Head circ.	56.3	.2	56.8	.1	57.0	.2	
–Height R	12.5	.1	12.9	.04	13.0	.1	
–Height L	12.5	.1	12.9	.04	13.0	.05	
Span total	180.4	.8	179.7	.4	182.1	.7	.0
–Akimbo	93.5	.5	93.2	.2	94.4	.4	.0
Ant. arm reach			90.2	.3	90.1	.5	
Biacromial			40.0	.1	40.7	.3	.0
Bideltoid	46.0	.3	46.6	.2	47.5	.3	.0
Chest circ.	94.9	.9	97.8	.5	98.3	.8	
–breadth	28.9	.3	29.9	.1	30.4	.2	
–depth	21.3	.3	22.7	.1	22.2	.2	
Abdom. depth	22.8	.4	24.5	.2	23.5	.3	.0
Bi-iliac	29.4	.2	30.0	.1	30.1	.3	
Calf circ. R	35.4	.4	36.2	.2	36.3	.3	
–L	35.1	.3	35.8	.2	36.0	.2	
Foot length	27.1	.2	26.7	.1	26.8	.1	
–breadth	10.3	.1	10.1	.03	10.1	.05	
Sitting ht.							
–erect	92.6	.3	92.0	.2	93.1	.3	.0
–normal	87.4	.4	87.4	.2	88.5	.3	.0
Trunk height	59.2	.3	59.9	.2	60.2	.3	
Eye level from seat	74.9	.4	74.6	.2	75.6	.3	.0
Buttock-knee	59.7	.4	60.3	.2	60.2	.3	
Knee height	55.7	.3	55.0	.2	55.1	.3	
Seat brd. (Bi-trochant.)	36.4	.3	37.0	.2	37.2	.3	
Shoulder-elbow	37.2	.2	37.3	.1	37.4	.2	
Elbow-middle finger	48.1	.4	47.5	.1	48.1	.1	.0
Knee brd. (bi-epic.)			20.7	.1	20.3	.2	
Elbow brd. (bi-epic.)	41.7	.5	44.5	.3	43.9	.4	
Hand length	19.3	.1	19.1	.1	19.4	.1	.0
–breadth	8.6	.05	8.7	.03	8.8	.05	
–circ.			20.7	.1	20.9	.2	
Ht./∛ wt.	12.79	.07	12.48	.04	12.57	.07	
Endomorphy	3.31	.15	3.58	.08	3.35	.13	
Mesomorphy	4.01	.10	4.61	.05	4.88	.09	.0
Ectomorphy	3.47	.16	2.45	.08	2.38	.12	
Dysplasia	3.12	.17	3.53	.10	3.53	.26	
Gynandromorphy	1.43	.08	1.66	.05	1.65	.14	
Grip R (lbs.)	129	2.6	121	1.1	129	1.8	.0
–L	115	2.1	113	1.0	118	1.8	
Laterality (L/R)–grip	89.6	1.3	93.7	.6	91.6	1.0	
–"squeezes"			88.9	1.7	84.3	3.8	

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[1] N = 49 for somatotype components.

[2] N = 203 for anterior arm reach, biacromial, bi-iliac, hand length, hand circumference knee breadth. N = 252 for somatotype components.

[3] N = 43 for anterior arm reach, biacromial, bi-iliac, hand length, hand circumference, plasia, and gynandromorphy. N = 25 for laterality of "squeezes."

* Where $p \leq .03$; based on figures before rounding off, which may distort the true si cance of differences.

calf girths (table 3). Interestingly enough, they were less mesomorphic but more "masculine" (less gynandromorphic), as well as more ectomorphic. They also had stronger right hands, both absolutely and relative to the left; and were less variable in endomorphy, gynandromorphy, and elbow-middle finger length. Despite these differences, reflecting regional as well as racial variation, they have been combined with the northeastern operators (table 2) to give a more representative nation-wide group of professional drivers. They are also presented separately in table 3.

As compared with the "general population" (table 2), regular drivers seem about the same height or negligibly shorter, but decidedly (at least 4 lbs.) heavier. Based on the samples in table 2 plus several others (e.g., Hooton, '36); Reynolds and Asakawa, '50) we estimate that the average American workingman of 37 is roughly 68.5 inches tall (174 cm) and weighs about 163 lbs. (74.1 kg). The drivers had a much greater chest girth, due partly to an age-associated fat increment but probably also to their greater mesomorphy. Other dimensions differed negligibly, but the drivers had a lower height/$\sqrt[3]{\text{weight}}$ index, probably more endomorphy, certainly more meso-, less ecto-, and less gynandromorphy. The drivers were about as variable as "normal" controls in metrical traits, but were significantly less variable in mesomorphy.

In sum, there was no single "truckdriver type," though drivers were stockier than the average American, more masculine, and not only more mesomorphic but more uniformly so.

Regular vs. champion drivers. Table 3 shows that the champions were younger and taller, with broader shoulders ($p < .02$), longer necks and faces (i.e., greater sitting height without longer trunk or higher head), longer forearms, longer heads ($p < .03$), and shallower abdomens. In addition, they were more mesomorphic and had stronger right hands. They tended to vary less in many dimensions (not somatotype components), reaching significance, however, only in age, left head height, and bi-epicondylar breadth across knees. For practical purposes, they were negligibly more homogeneous than drivers generally, who, as already noted, were no more homogeneous than the working population.

The pattern of difference between regular and champion drivers suggests Howells' ('52) Factor II or McCloy's "omomorphy," as described by Sills ('50), with strength concentrated around the shoulder girdle and upper extremity. The champions add stem and forearm length increments at no sacrifice in mesomorphy — in fact, with a gain. This is their outstanding feature: an excess of mesomorphy in an ocupational group already characterized by high mesomorphy.

Military drivers. Compared to the total series of 25,000 soldiers reported by Newman and White ('51), the 2500 Army drivers were 0.6 year younger (23.8 vs. 24.4 years) and 9 mm shorter (1729 vs. 1738 mm), but weighed the same (155 lbs.). They were smaller in 14 other dimensions, breadths as well as lengths, but by minute amounts — a few millimeters, small fractions of a standard deviation — made statistically "significant" by the enormous number of subjects. Chest circumference, head height, and hand and foot length and breadth did not differ. Variability was equal in 11 of 22 dimensions, while in the rest (6 body lengths, three breadths, chest depth, and head circumference) the drivers were more variable, again mostly by fractions of a coefficient of variation point.

It is hardly worth while to attempt to explain these minute differences in dimensions and variability: possibilities include the drivers' youth, the "wastebasket" nature of this military specialty, or — remotely — small size imposed by restricted quarters, as in tanks. Though statistically significant, the differences have no practical bearing on equipment design and little for occupational anthropology. They show minimal or negligible differences between Army drivers and soldiers generally.

DISCUSSION

On the whole, our findings were less dramatic than the popular stereotype of the "big burly truckdriver" would lead one to expect. Burly they were, being stockier, more mesomorphic, and less gynandromorphic than the average American, but bigger only in weight and associated breadths and girths, not in stature or body lengths. Champion truck drivers were taller, with broader shoulders and longer forearms, and even stronger and more mesomorphic than the run of the drivers. (The champions were no more mesomorphic than Northeastern truckmen, but the combined regular bus, truck, and Texas drivers were a better control group, for reasons already given.) Galton (1869) and Gowin ('18) likewise found leaders in various pursuits to be taller than average performers. However, neither ordinary nor superlative drivers fell within a narrow range of physique; except for consistently high mesomorphy, drivers were no more homogeneous physically or in ancestry than Americans in general.

There seems then to be a real association of physique with heavy vehicle driving as an occupation. Precisely what and how much can be determined only when comparable data become available for the general population and for other groups within it. The present data confirm previous authors' findings as to drivers' muscularity and large chests, both absolutely and relative to stature, but not as to their increased stature. Like most other workers, we found that body build patterns, whether indices, combinations of dimensions, or somatotype, differentiated more sharply and comprehensibly among groups than did lists of separate measurements; but the latter when judiciously chosen are indispensable.

The physical similarity of bus and truck drivers may mean that operating heavy vehicles is basically one occupation, with common factors outweighing the most obvious job difference, "meeting the public." More endomorphy, with associated weight, breadths, and girths, might have been expected among the busmen from Sheldon's ('42, p. 419) correlation of + .79 between viscerotonia — which includes "sociophilia" — and endomorphy. The busmen were significantly less mesomorphic than the truckmen — though both exceeded Sheldon's 90th percentile —, without apparent relation to job activity, as Brezina and Wastl's ('29) Viennese streetcar conductors were less "athletic" in physique than motormen. Many drivers had shifted freely between buses and trucks, while others had remained with one type of vehicle because of strong feelings for or against "meeting the public."

TABLE 4

Somatotypes of bus and truck drivers, flyers, and champion woodcutters

	REGULAR DRIVERS		AIR FORCE FLYING OFFICERS [1]		CHAMPION DRIVERS		SUCCESSFUL COMBAT PILOTS [1]		CHAMPION FINNISH WOOD-CUTTERS [2]	
NUMBER	252		150		103		156		40	
	M	s.e.	M	s.e.	M	s.e.	M	s.e.	M	s.e.
Endomorphy	3.58	.08	3.13	.08	3.35	.13	2.81	.09	2.42	.09
Mesomorphy	4.61	.05	4.24	.08	4.88	.09	4.70	.05	5.32	.11
Ectomorphy	2.45	.08	3.06	.09	2.38	.12	2.99	.10	2.86	.11
Gynandromorphy	1.66	.05	2.08	.07	1.65 [3]	.14	1.70	.06		

[1] Damon ('55).
[2] Rated from photographs kindly supplied by Dr. M. J. Karvonen.
[3] N = 43.

The Texas truckmen reflected the physique popularly associated with the cowboy — tall, lean, strong, and hard (less feminine). Mesomorphy and masculinity, often associated (r of + .48 found by Sheldon '42, p. 405), varied independently here, with the Texans significantly less mesomorphic but more masculine than Northeastern drivers. Other examples have been noted among Air Force flyers (Damon, '55). Incidentally, ectomorphy need not vary with height: the champion drivers, taller but no heavier than the regulars, were no more ectomorphic.

It may be of interest to compare the drivers' somatotypes with those of other occupational groups rated by the same observer. Table 4 shows that both regular and champion drivers were more endo-, more meso- (the champions' excess being insignificant), and less ectomorphic than their Air Force counterparts. Both groups of drivers and the successful combat pilots — Air Force "champions," in a sense — were less gynandromorphic than the recently graduated Air Force flying officers. Understandably enough, the champion Finnish woodcutters, reported elsewhere (Eränkö and Karvonen, '55) were even more mesomorphic than the champion drivers; in addition, they were less variable in all three somatotype components. Thus the drivers, while highly mesomorphic, were not excessively so.

Military drivers deserve separate discussion. They were younger and generally smaller than other soldiers, but by minute and negligible amounts. These were the same subjects for whom Hooton ('48, p. 88) wrote: "On the whole, the transportation group does not depart radically from the total series distribution, but it is more muscular than average." While it might be tempting to consider this another instance of body type analysis succeeding where standard anthropometry failed, Hooton's data actually support the first part of his statement rather than the second.

Many of the questions raised in our Introduction must remain unanswered. As often mentioned, comparable control data are sorely missed. Our conclusions may be modified by future findings that, for example, the American workman is more mesomorphic than currently believed. The present study may help establish such physical standards for American workingmen. Application of the data to vehicle design is under way (McFarland, '54; McFarland *et al.*, '55). Moreover, if the occupational correlates of physique reported here are confirmed in other samples, occupation will have to be given more attention in future studies of physique, as will psycho-biological factors in the social scientists' research into vocational choice. It may become possible to map jobs according to the patterns of physique and temperament found among successful workers, thereby aiding vocational guidance and selection.

Some light may be thrown on the etiological factors and occupational incidence of certain diseases by our finding that the drivers were predominantly endomorphic mesomorphs, as reported of patients with coronary artery disease (Gertler *et al.*, '51; Spain *et al.*, '53), duodenal ulcer (Sheldon, '49, p. 789), and Meniere's disease (Damon *et al.*, '55). Thus, the relative frequency among bus drivers of coronary artery disease (Morris *et al.*, '52, '53) may be an association, in some part at least, with the drivers' physique as well as with environmental aspects of their work like physical exertion and mental stress.

The case is not quite so clear for peptic ulcer, though the same possibility remains. Not only have other observers (Draper *et al.*, '44; Wretmark, '53) stressed the linear rather than the endomorphic-mesomorphic physique in ulcer patients, but despite Hill's ('37) finding of a high incidence of digestive disturbances among drivers, Doll and Jones ('51) found no excess of ulcers in this group.

Our data indicate that heavy vehicle driving is a job of, if not for, the mesomorph low in gynandromorphy, and that the best drivers are even more mesomorphic. This finding parallels that for military flyers (Sheldon, '43; McFarland and Franzen, '44; Damon, '55), probably reflecting common factors in the two occupations, and contrasts sharply with the predominant ectomorphy of research workers (Garn and Gertler, '50). While 12% of ordinary drivers and even 8% of the champions rated less than 4 in mesomorphy, a youth so poorly endowed would appear ill-advised, all other things being equal, to choose this occupation. By using the same criterion for hiring drivers, an employer would probably gain much more by preventing failures than he would lose by eliminating potential successes.

Why should mesomorphy be so important for the heavy vehicle driver? Garn and Gertler ('50) attributed the ectomorphy of their 20 research workers to a predominantly negative type of selection: it is not so much that ectomorphs make good researchers as that the job affords a haven for cerebrotonic weaklings. The drivers' mesomorphy, however, has a positive selective value, both physically and temperamentally. To be sure, mesomorphs are strong (Sheldon, '42; Jones, '47), but far less strength is needed to drive modern heavy vehicles than a team of horses. Nor can the exertion of handling cargo be invoked, for the 27 champion truckmen with city pick-up and delivery routes were no more mesomorphic than the other 76 over-the-road drivers. Many jobs make greater physical demands, but we venture to predict that in few of them will workers match the drivers' mesomorphy. Perhaps significantly, most of the strength that *is* required, is in the arms and hands, just those regions where the champions surpass ordinary drivers.

Mesomorphy involves more than strength alone. With it goes a complex of physical and temperamental attributes, such as motor abilities (Sills, '50), perhaps visual acuity (Hooton, '45), physical endurance and coordination, relative insensitivity to discomfort, fear, and distracting stimuli, and ready habit formation (Sheldon, '42). All are necessary for the successful driver of heavy vehicles.

How does the association of physique and occupation become established? Some evidence favors selection and adaptation (i.e., survival of the fittest) over environmental — in this case, occupational — influence on physique, though the latter certainly occurs. Research work does not "make" ectomorphs, nor does driving "cause" mesomorphy. Even if work molded physique markedly, the wide variety of physiques within one occupation — here, driving — would reflect innate differences in susceptibility to such influence. The truth is, as Schlegel ('50a) pointed out, that work imposes far less stringent physical demands than sport. This is confirmed by the lower mesomorphy of Karvonen's champion Finnish woodcutters, legitimate lumberjacks all, than of Tappen's ('50) champion weight-lifters (4.88 vs. 6.51). Seltzer ('46a) and Tanner ('52) have shown the relatively slight, transient, and variable effect on physique of physical conditioning more severe than that encountered in most jobs and certainly more than in driving. The same result emerged from a comparison of calf girths among drivers and non-drivers (Damon and McFarland, '53). Activity analysis in buses and trucks showed that the driver's right foot was in use 99% of the time, his left only 48%. It was thus anticipated that both calf circumference and right-minus-left calf circumference would be larger among drivers than non-drivers — or at least different, in view of Tanner's ('52) observation that calf girth may actually *decrease* with severe exercise. No difference was found.

The tentative formulation may thus be ventured that jobs require specific patterns of physique and temperament for success, such patterns varying in strictness and in detail with the nature of the job. People choose jobs for various reasons, among them physical and temperamental affinity, so that there is self-selection even among novices in an occupation. Those who succeed will on the whole tend to fit even more closely the pattern demanded by the job. This whole selective process will be reflected in the worker's physique to the extent (a) that the pattern is narrow; (b) that this system operates free from disturbing socio-economic influences; and (c) that physique and temperament are correlated.

SUMMARY

Occupational anthropometry has been somewhat neglected despite its relevance to physical anthropology, engineering, medicine, psychology, and vocational placement. A review of the literature showed some consistent occupational differences in physique, often but not always related to the exertion required. Differences among apprentices in various trades, among workers in jobs involving the same expenditure of energy, and among good, fair, and poor workers within one occupation likewise indicated a reciprocal relationship between job and physique, with selection and adaptation more evident than direct influence of work on physique. Physiological processes like maturation and ageing could differ even more

than physique, again with no apparent relation to the job. Descriptions of body build were often better than separate dimensions for differentiating among groups.

Some of these previous findings were confirmed in an anthropometric study of 375 professional drivers of heavy vehicles, members of perhaps the largest distinct occupational group in the United States. They included 103 bus and 104 truck drivers from New England and New York, 65 Texas truckmen, and 103 champion truckmen representing every state. The drivers averaged 36.8 years in age, with 10 years of professional driving. Regular bus and truckmen from the Northeast differed only in mesomorphy (truckmen higher) and dysplasia (truckmen lower). The Texans were taller, leaner, less mesomorphic, but more "masculine" and stronger (the cowboy stereotype) than the Northeasterners. Compared to the few available — and not quite comparable — "normal" series from the literature, the three groups of regular drivers combined were about as tall as the average American, but heavier and stockier, with larger chests, possibly more endo-, and decidedly more meso-, less ecto-, and less gynandromorphy.

The champions were younger and taller than regular drivers, with broader shoulders, greater sitting height, longer forearms, shallower abdomens, and more mesomorphy. Thus, as with Air Force flyers, outstanding performers were even more mesomorphic than the average of a highly mesomorphic occupation. However, the champions' mesomorphy was less than that of champion Finnish woodcutters or champion American weight-lifters.

This association of physique with bus and truck driving did not hold for military drivers, 2500 of whom were compared with their parent population of 25,000 soldiers studied by the Quartermaster Corps at the end of World War II. However, the soldiers averaged but 24 years of age, with less than two years' total military service, only part of which was spent in driving a variety of vehicles.

The significance of the present findings, and some of their implications for the fields mentioned, were discussed. It was suggested that since the drivers were predominantly endomorphic mesomorphs, a physique reported to be especially prone to coronary artery disease, the relative frequency of this disease among drivers might reflect their physique as well as such environmental aspects of their work as exertion and mental stress.

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BRIEF COMMUNICATION

THE HARPENDEN SKINFOLD CALIPER

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ONE FIGURE

There are now available several ways of estimating the proportion of fat in the body. One of them is by measuring the thickness of folds of skin and subcutaneous tissue pulled away between the thumb and forefinger from the underlying structures. This method has the great merit of simplicity and cheapness, and though it probably cannot estimate total body fat with the accuracy of underwater weighing or chemical dilution methods it gives information about regional fat distribution which these others do not.

The thickness of the fold of skin and subcutaneous tissue is measured by applying some form of caliper to either side of it, and the reading obtained is dependent on the form and characteristics of the caliper used. If, for example, the jaws of the caliper are approximated by a spring, the reading will depend on the strength of the spring, since the tissue is compresssible. Despite this, there has been little information published on the best design for these calipers until very recently, when at the request of the Medical Research Council an extensive investigation was set in train (Edwards, Hammond, Healy, Tanner and Whitehouse, '55). This paper should be consulted for the experimental results, but the recommendations emerging can be summarized as follows:

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1. The faces of the calipers should be rectangular of size 6 × 15 mm, with well rounded edges and corners.
2. The pressure at the faces should not vary by more than 2.0 gm/mm^2 over the range of openings 2–40 mm.
3. For results which can be reproduced with accuracy,, the pressure should lie in the range 9–20 gm/mm^2. The pressure of 10 gm/mm^2 is suggested as a standard value.
4. The scale of the instrument should be such that readings can be taken preferably to the nearest 0.1 mm.

A skinfold caliper which meets these requirements was developed at the Harpenden Growth Study (see Tanner, '55) and has now been used extensively by several investigators during the last 18 months. This instrument, illustrated in figure 1, is an adaptation of a device used in industry for measuring the thickness of pieces of plywood, metal or leather, and is available commercially from British Indicators Ltd., Sutton Road, St. Albans, Herts, England. The most difficult requirement to meet is that of constant pressure at the faces over the whole opening range, and this has been done by placing the springs so that their perpendicular distance from the fulcrum decreases, as the jaws are opened, just sufficiently to counteract the increase in tension in the springs. The caliper is convenient to handle, robust, and easily readable to 0.1 mm. In our experience it is the most satisfactory instrument of this type yet produced.

The accuracy with which skinfold measurements may be taken with this caliper is reported in the paper cited (Edwards, Hammond, Healy, Tanner and Whitehouse, '55). Duplicate measurements at the same site by the same observer agree more closely for small than for large readings, the measuring error increasing roughly in proportion to the size of the measurement. Also the distribution of most skinfold measurements in the general population is considerably skew, with a long tail of high readings. For both these reasons it is desirable to transform the measurements to a logarithmic scale before analysis and we routinely use the transform

$$Z = 100 \log_{10} (\text{reading in } 1/10 \text{ mm} - 18)$$

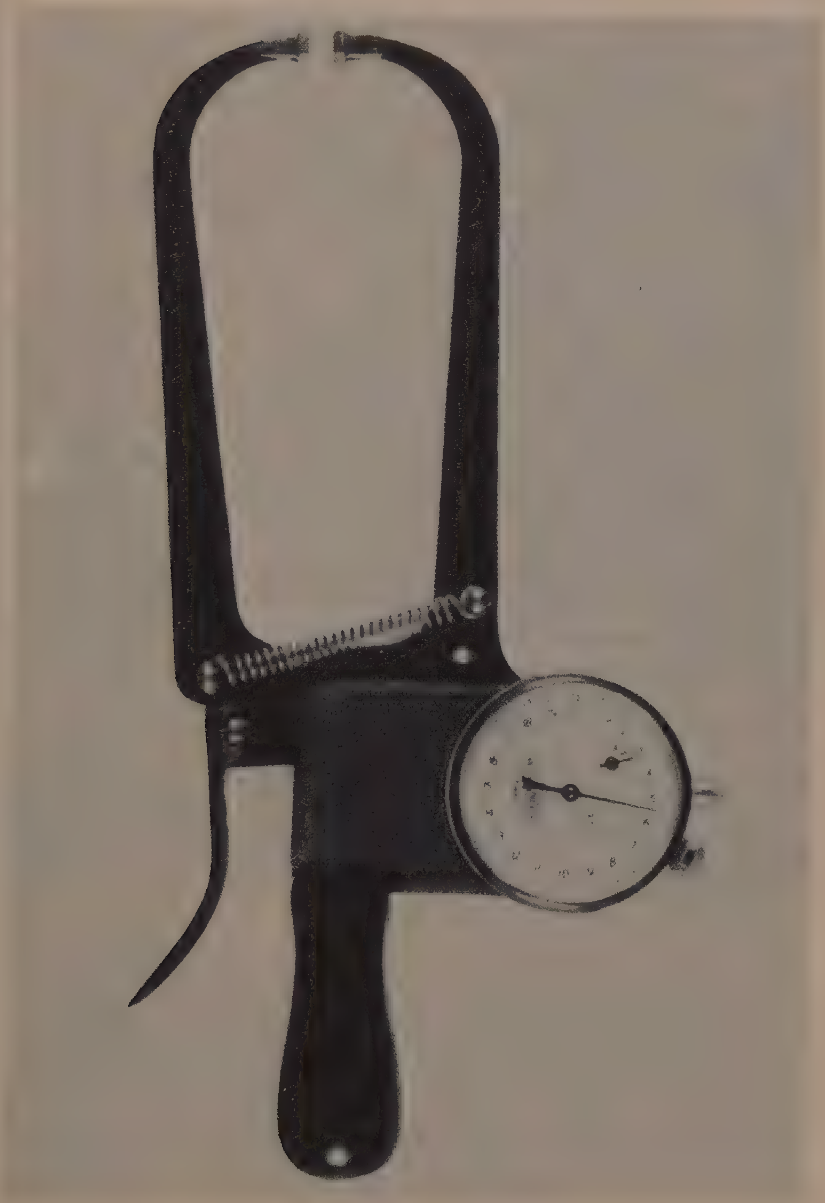

Fig. 1 The Harpenden Skinfold Caliper. The large hand can make two complete revolutions, the first measuring from 0 to 20 mm, the second from 20 to 40 mm. The position of the small hand indicates whether one is in the 0 to 20 or 20 to 40 mm phase. The maximum measurement registerable is 50 mm.

which approximately normalizes the distributions. A table of this transformation is given in the paper referred to. An equation for converting the values obtained with the usual Franzen-type calipers (which produce pressures of the order of 2 gm/mm² at 3 mm opening and 8 gm/mm² at 40 mm opening) to Harpenden Skinfold Caliper Transform values is given in Tanner ('55, appendix).

With the new caliper the standard deviations of the differences between duplicate measurements taken by a single observer at the triceps, subscapular and supra-iliac sites were 2–4 units in the logarithmic scale, equivalent to 0.3–0.6 mm at a jaw opening of 7 mm. The differences between duplicates taken by different observers are greater, even when the sites for measurement are marked on the body; the figures are roughly twice as large as those for a single observer. The limitations of accuracy when this caliper is used are transferred from the instrument to the locating of the skinfold and the manner in which it is picked up, limitations analogous to those encountered in classical skeletal anthropometry.

LITERATURE CITED

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TANNER, J. M. 1955 Growth at Adolescence. Oxford: Blackwell and Springfield: Thomas.

BOOK NOTES

BASIC READINGS ON THE IDENTIFICATION OF HUMAN SKELETONS. ESTIMATION OF AGE. Edited by T. D. Stewart and Mildred Trotter, pp. iv + 347. Wenner-Gren Foundation for Anthropological Research, Inc., New York. 1954.

This book is a compilation and reprinting of basic source reports dealing with problems of identification, and specifically with estimations of age. Ten reprinted articles are grouped under 4 headings and introduced with short critical comments by the editors. Eruption of teeth, appearance and fusion of epiphyseal centers, metamorphosis of bones of pelvic and shoulder girdles, and cranial suture closure make up the divisions treated by the various authors. Kronfeld, Meredith, Hurme, Stevenson, Flecker, Todd and d'Errico, Graves and Todd and Lyons author the various selections. We are indebted to the editors and to the Wenner-Gren Foundation for making this reference material readily available and in such a coherent form.

F.P.T.

THE STRUCTURE, COMPOSITION AND GROWTH OF BONE. 1930–1953. A BIBLIOGRAPHY. Compiled by Marjory C. Spencer and Katherine Uhler, pp. x + 190. Armed Forces Medical Library, Washington, D. C. 1955. (For sale by Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C. $1.00.)

The world literature, 1930 to 1953, dealing with bone has been noted in this comprehensive bibliography and listed by categories of subject matter. Many articles are abstracted and cross referencing between sections is carefully done. The result is a complete working bibliography which is invaluable, available and inexpensive.

F.P.T.

CHILDREN'S BODY MEASUREMENTS FOR PLANNING & EQUIPPING SCHOOLS. Special Publication No. 4. U. S. Dept of Health Education and Welfare. Office of Education. 1955 (U. S. Gov't Printing Office. $0.50.)

This publication is a rearrangement of data previously published In its present form, as a handbook for school officials and architects, it is available for wide distribution and may well serve as a basis for a more efficient redesign of school equipment in our expanding school system. It is valuable for anthropologists interested in the body measurements of modern school age children.

F.P.T.

MAN ON EARTH. By Jacquetta Hawkes. Random House, New York. 1955.

A popular account by a professional archaeologist and anthropologist of the story of man's becoming, with less attention to the details of the record than to the fabric and grandeur of the story.

F.P.T.

EXPRESSION OF THE EMOTIONS IN MAN AND ANIMALS. By Charles Darwin, pp. xi + 372. Philosophical Library, New York. 1955.

This book is a new edition of Darwin's original inquiry. An introduction by Margaret Mead and several new plates have been added to the original.

F.P.T.

ADAPTIVE HUMAN FERTILITY. By Paul S. Henshaw, pp. 322. Blakiston Division, McGraw-Hill Book Co., New York. 1955.

This book offers a description of fertility process and present problems arising from over population. It proposes a solution based on rational controls. 'Adaptive' as used in this book means the possibility of changing fertility trends and does not mean the detailed interplay between the biology of fertility and the environment of man.

F.P.T.

POPULATION GENETICS. By C. C. Li, pp. ix + 366. $10.00. University of Chicago Press, Chicago. 1955.

Professor Li has added much material to his earlier book of the same title, so much so that this is not really a second edition but a new book. The subject matter, important to anthropologists who must rely on this systematic approach when dealing with man, is expertly treated and truely a foundation for the study of human genetics. While it is a source of much original material, it is still a teaching text which gives example problems and careful exposition of the material. An excellent and important book.

F.P.T.

FAMILY AND FERTILITY IN PUERTO RICO. By J. Mayone Stycos, pp. 332. $6.00. Columbia University Press, New York. 1955.

Puerto Rico, that land more troubled by excess fertility than from any other cause, is intensively studied by the author in an attempt to reveal the set of attitudes and practices of lower class people in respect to fertility. When dealing with such problems, culture more than biology and history more than hormones are at the root. The author gives us a factual report, and it is clear that socio-cultural factors must be considered first if we are to understand human fertility and its variability between demographic units of the world.

F.P.T.

ASPECTS OF SYNTHESIS AND ORDER IN GROWTH. Edited by Dorothea Rudnick, pp. vii + 274. $6.00. Princeton University Press, Princeton, N. J. 1954.

Beginning with an essay by Linus Pauling on the duplication of molecules, this record of the 13th symposium of the Society for the Study of Development and Growth includes the original articles of 11 investigators. While there is little here that would be normal to an anthropologist's idea of human growth, it is nevertheless basic to any ideas on the subject, and maybe we must eventually get closer to the physical chemical level before the regularities at the gross phenotypic levels will be understood.

F.P.T.

RESEARCH FILMS IN BIOLOGY, ANTHROPOLOGY, PSYCHOLOGY AND MEDICINE. By Anthony R. Michaelis, pp. xvi + 490. $10.00. Academic Press Inc., New York. 1955.

Not only does the author list important research films for each subject mentioned in his title, but there is a detailed and expert discussion of techniques needed to make the films related to the special problems and interests of each discipline. From techniques needed for making movies of spermatozoa to listing films on the migrations of pastoral peoples, this book seems complete and an important summary of how films can be used as a tool in research.

F.P.T.

BIOESTADISTICA. By Alfonso Dominquez Toledano, pp. 180. No. 2, Serie Cientifica. Museo Nacional de Antropologia, Mexico. 1953.

This book is an elementary text intended for use in teaching biometry. It covers the usual statistical tools and proceeds to a discussion of covariance. It appears to be concise and thorough and would probably make a fine working textbook for students of biometry.

F.P.T.

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